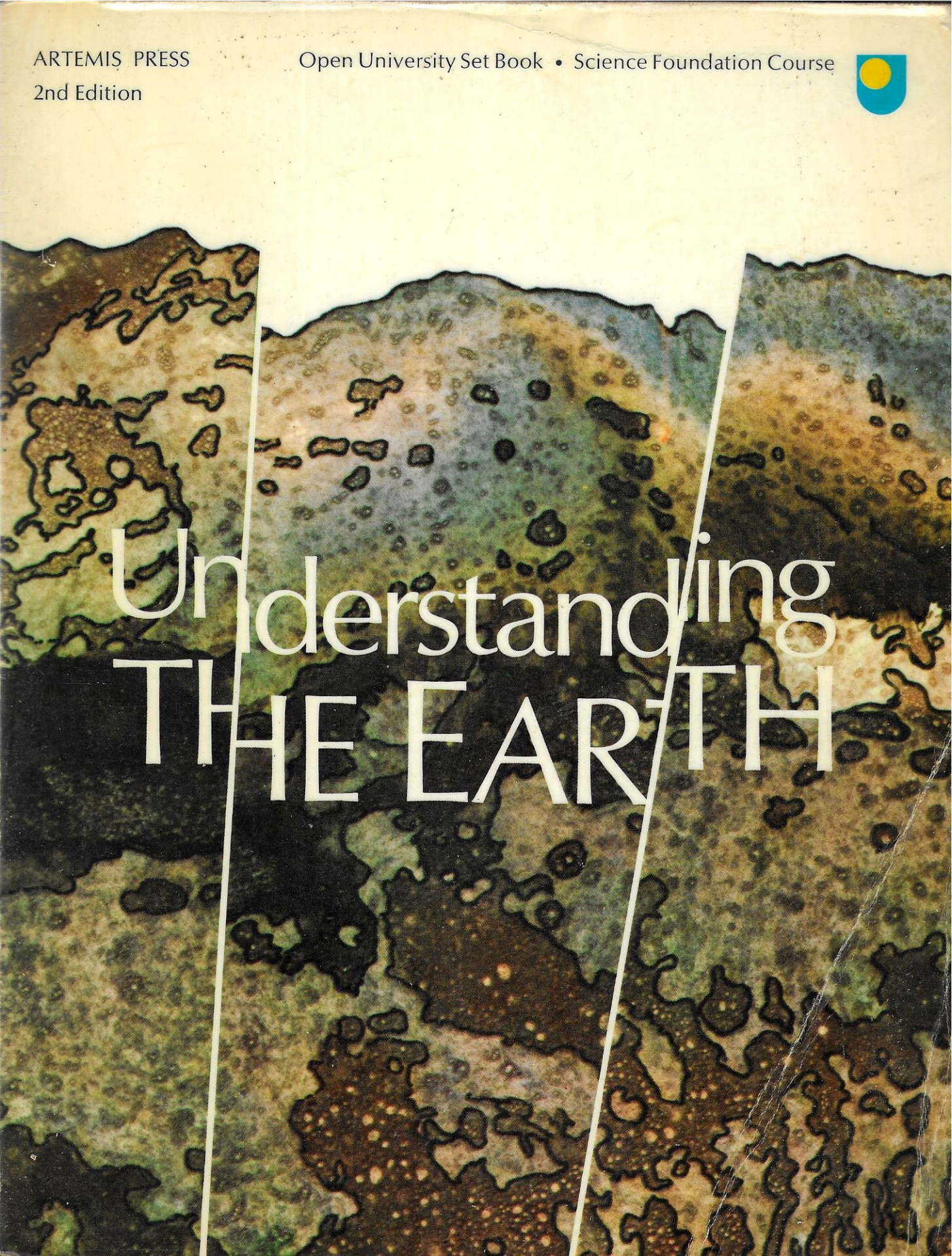


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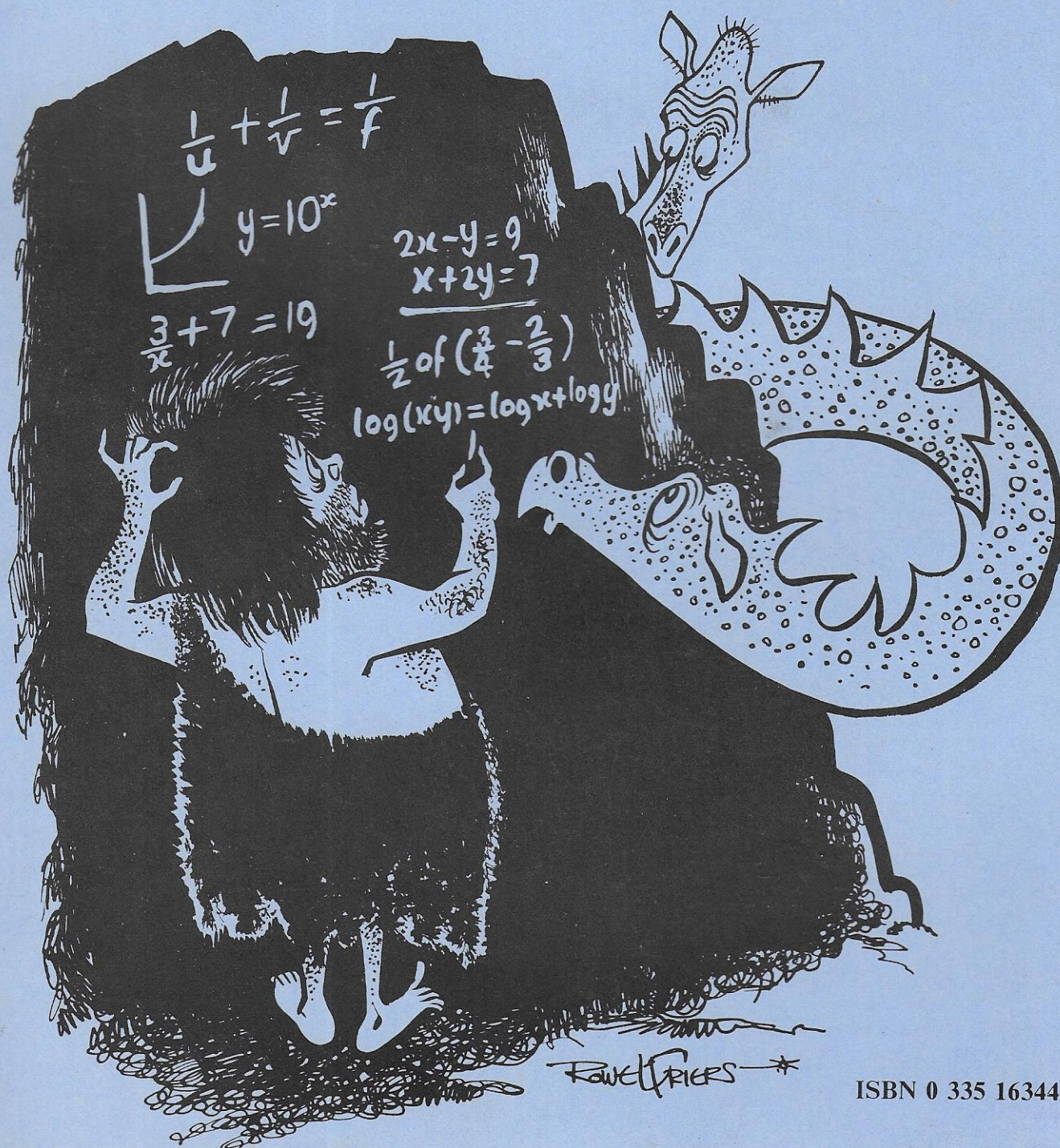
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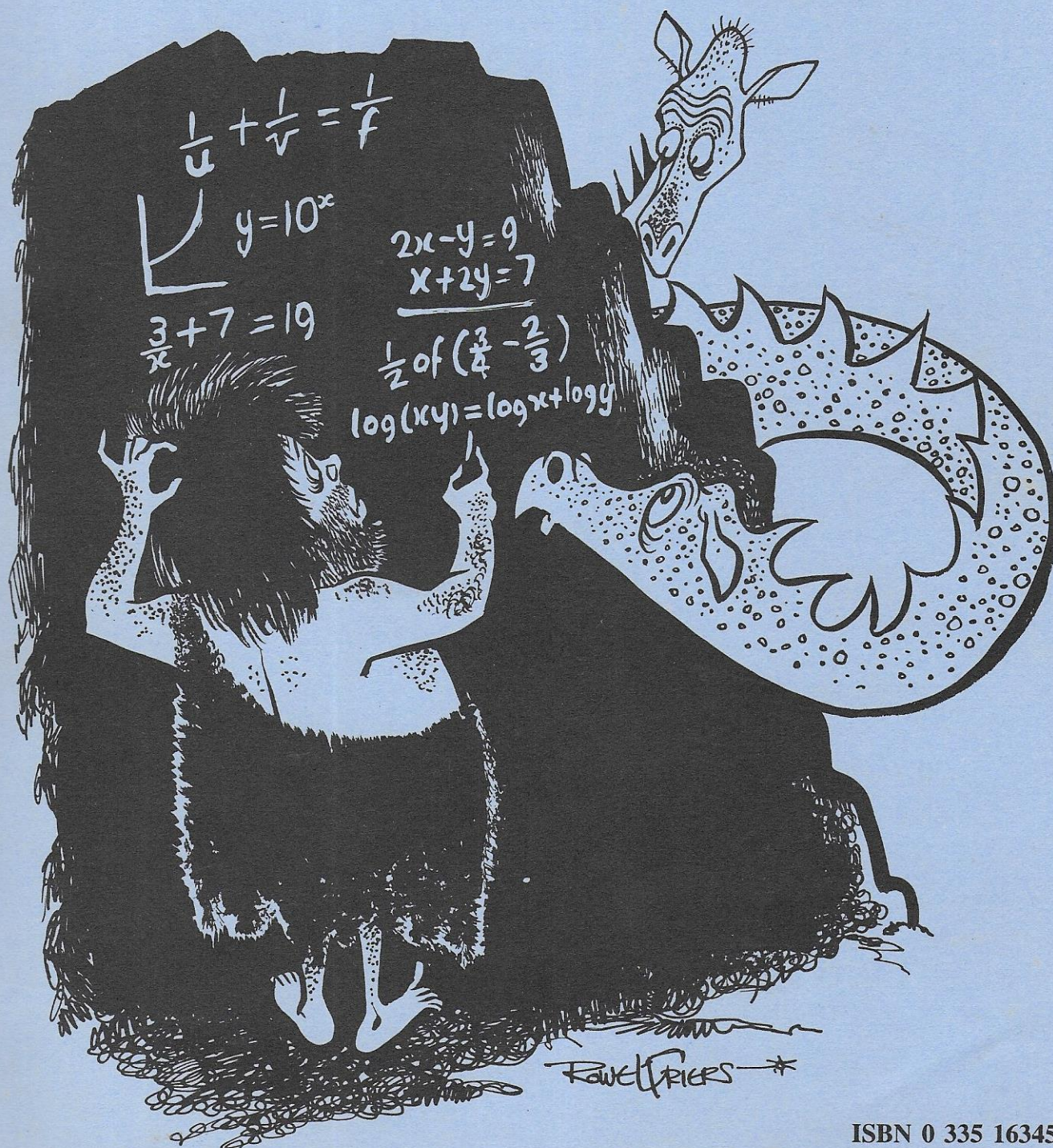




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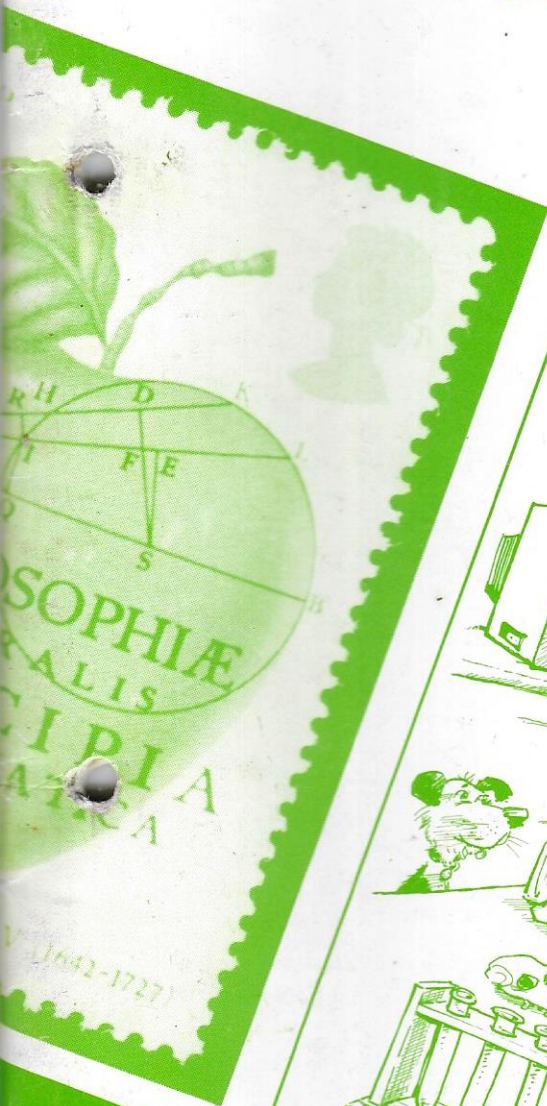


THE
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Preparing for the

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THE RESTLESS UNIVERSE

Robert Lambourne and John Bolton



The PHYSICAL WORLD

The restless Universe offers a fascinating overview of the 'big ideas' that have shaped physics from the time of Kepler to the present day. Using little mathematics, the book surveys fundamental features of key physical theories and provides the essential context for the further study of physics. The main developments covered are the mechanical Universe, thermodynamics, electromagnetism and the concept of fields, special and general relativity, quantum mechanics and quantum field theory.

Alongside theories of scientific discovery, the book features biographical insights into the lives of leading physicists and raises issues such as the conflict between free will and determinism, and the contrast between reductionism and emergent phenomena.

The restless Universe is in a series of books which, along with interactive multimedia, is used in the Open University course *The Physical World*. Each book combines richly illustrated text with questions (and answers) for self-assessment, and is ideally suited for students working independently.

The complete list of titles in the series *The Physical World* is:

The restless Universe

Describing motion

Predicting motion

Classical physics of matter

Static fields and potentials

Dynamic fields and waves

Quantum physics: an introduction

Quantum physics of matter



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S207 Book 1

ISBN 0 7492 8071 9

DESCRIBING MOTION

Edited by Robert Lambourne and Alan Durrant



The PHYSICAL WORLD δ

Describing motion concerns the quantitative description of a variety of physically important motions. Starting with simple examples of motion along a line, key concepts, such as position, velocity and acceleration are introduced and expressed using the fundamental rules of differential calculus. A study of projectile motion is used to generalize the discussion to two and three dimensions and to introduce the important idea of a vector. The descriptive power of calculus and vectors is then illustrated by studying a variety of repetitive periodic motions, including the circular motion of communications satellites, the simple harmonic motion of pendulums and mechanical oscillators, and the elliptical orbits of planets and space probes.

Describing motion is in a series of books which, along with interactive multimedia, is used in the Open University course *The Physical World*. Each book combines richly illustrated text with questions (and answers) for self-assessment, and is ideally suited for students working independently.

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S207 Book 2

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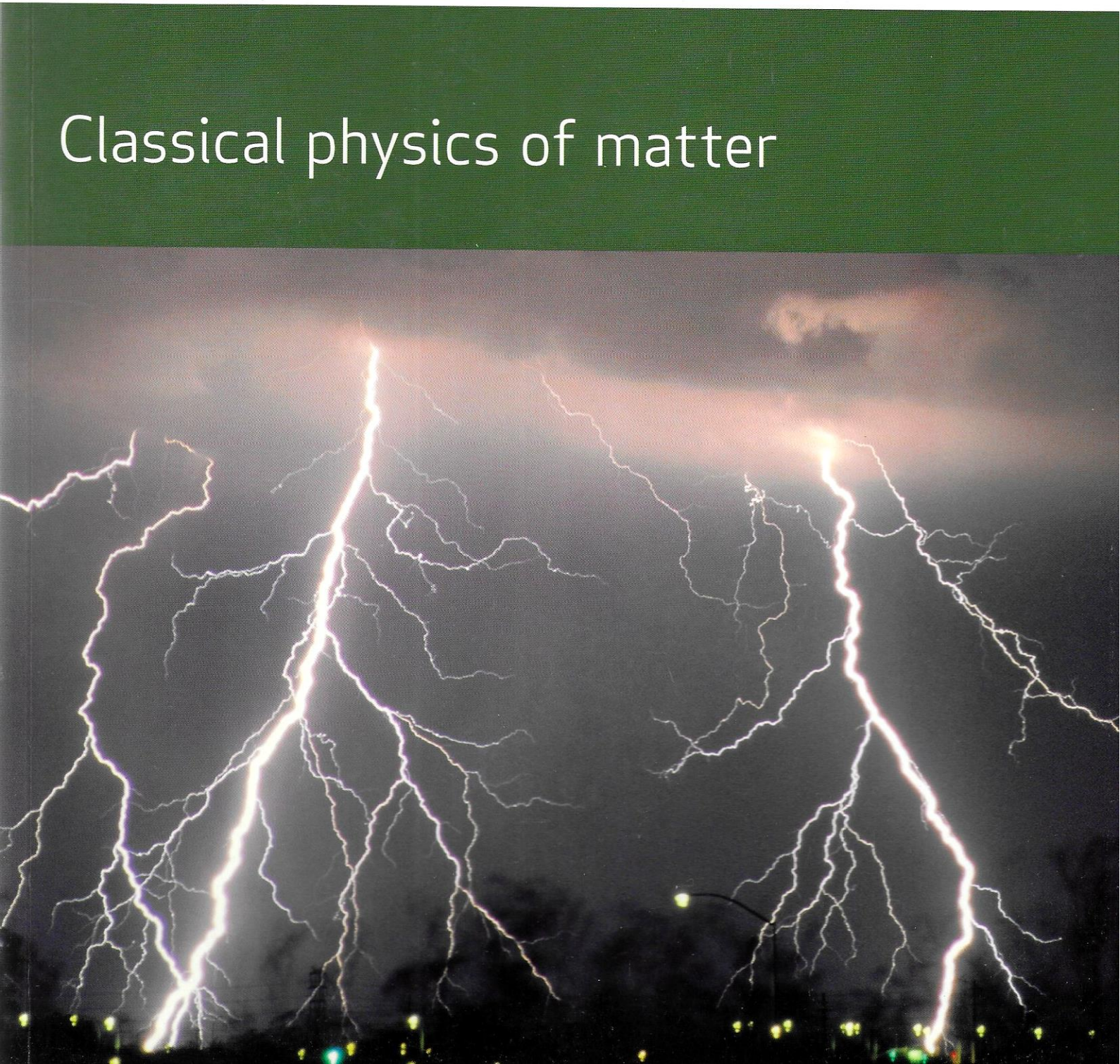
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- Book 4 Classical physics of matter
- Book 5 Static fields and potentials
- Book 6 Dynamic fields and waves
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Book 7 Quantum physics: an introduction

Book 8 Quantum physics of matter

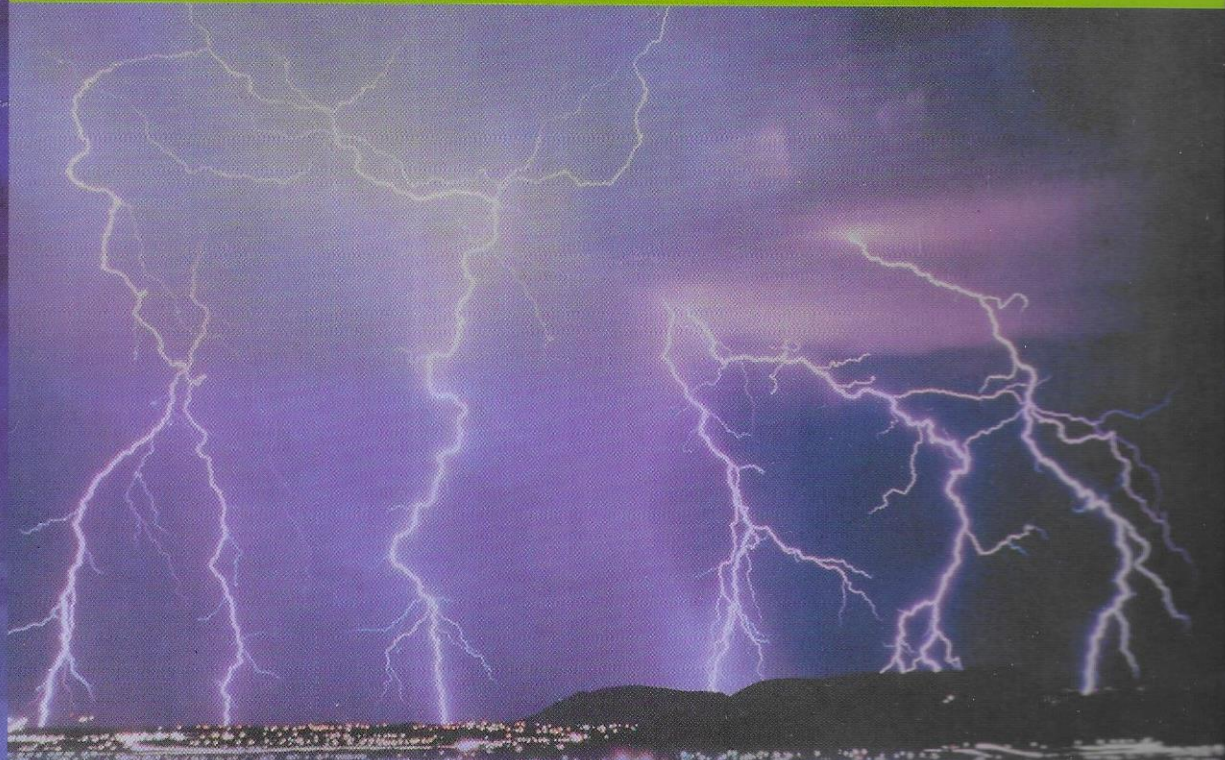
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STATIC FIELDS AND POTENTIALS

Edited by Joy Manners



The PHYSICAL WORLD δ

Static fields and potentials begins by looking at the general ideas of fields with particular reference to gravitational and electrical fields which provide examples of vector fields, and gravitational and electric potential which are scalar fields. The relationships between fields, forces, potentials and potential energies are then discussed. The book also covers electric currents, simple circuits, magnetic fields and their generation, the Lorentz force law and the behaviour of charged particles in magnetic and electric fields. A wide variety of relevant natural phenomena and technical applications are included, for example, liquid crystal displays, thunderstorms, stellar evolution, resistance sensors, cyclotrons and the aurora.

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DYNAMIC FIELDS AND WAVES

Edited by Andrew Norton



The **PHYSICAL WORLD** δ

Dynamic fields and waves concerns the unification of electricity, magnetism and light. The phenomenon of electromagnetic induction is described and shown to underpin everyday technology from electricity generation to radio reception. Maxwell's theory of electromagnetism is then introduced along with the electromagnetic spectrum, and the physics of light and sound waves is explored in detail. Reflection, refraction, diffraction and interference of waves are explained and the principles behind optical instruments such as microscopes, telescopes, cameras and the human eye are investigated. Finally, light is shown to be the key to understanding Einstein's special theory of relativity, including time dilation and length contraction.

Dynamic fields and waves is in a series of books which, along with interactive multimedia, is used in the Open University course *The Physical World*. Each book combines richly illustrated text with questions (and answers) for self-assessment, and is ideally suited for students working independently.

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R. Lambourne

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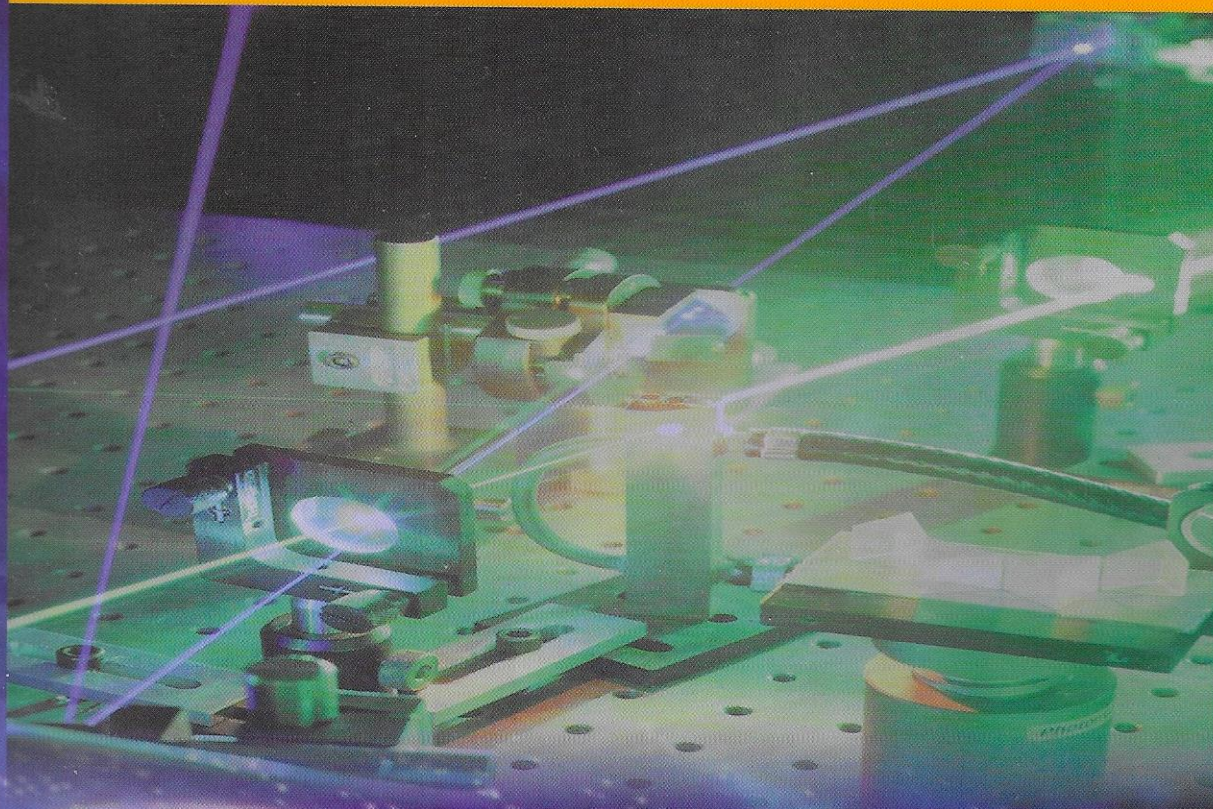
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9 780750 307192 >

QUANTUM PHYSICS: AN INTRODUCTION

Edited by Joy Manners



The PHYSICAL WORLD δ

Quantum physics: an introduction discusses the quantum revolution, beginning with a description of five problems which, at the end of the nineteenth century, were found to be intractable from the viewpoint of classical physics. A discussion of the resolution of these problems, through the introduction of the concept of a quantum of energy, launches our exploration of quantum physics. The principles of quantum mechanics are discussed, based on Schrödinger's wave mechanics, and these are applied to particles in some simple situations and to the quantum physics of atoms. We also look at the 'shape' of the hydrogen atom and the origins of complicated atomic spectra. There is a concluding discussion of the interpretation of quantum mechanics.

Quantum physics: an introduction is in a series of books which, along with interactive multimedia, is used in the Open University course *The Physical World*. Each book combines richly illustrated text with questions (and answers) for self-assessment, and is ideally suited for students working independently.

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QUANTUM PHYSICS OF MATTER

Edited by Alan Durrant



The PHYSICAL WORLD δ

Quantum physics of matter shows how quantum mechanics is applied to describe matter on the macroscopic and microscopic levels. Chapter 1 explores the quantum physics of gases, developing the idea of a quantum gas that can describe a variety of macroscopic systems including the electrons in metals and the photons in the Sun. Chapter 2 describes solids and their electrical properties, leading to a discussion of solid-state devices including solar cells and laser diodes. The next two chapters focus on the subatomic world. Chapter 3 discusses radioactivity, models of the atomic nucleus, and nuclear reactions including fusion and fission. Chapter 4 is concerned with the physics of fundamental particles and their interactions.

Quantum physics of matter is in a series of books which, along with interactive multimedia, is used in the Open University course *The Physical World*. Each book combines richly illustrated text with questions (and answers) for self-assessment, and is ideally suited for students working independently.

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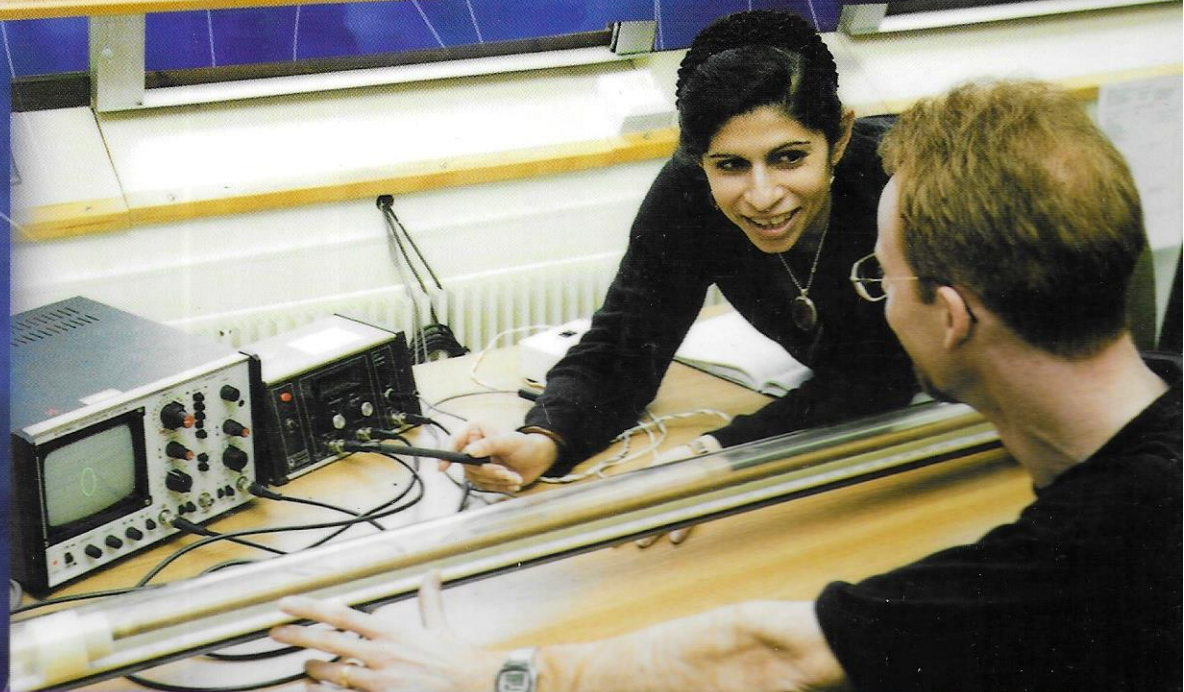
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PHYSICS BY EXPERIMENT



A PRACTICAL HANDBOOK

Stuart Freake

Physics by Experiment: A Practical Handbook introduces a range of practical skills that will be useful for students who are undertaking laboratory work in physics. Experiments have played — and continue to play — a crucial role in developing our understanding of the physical world, and the best way to get a feel for the role of experiments is to do some for yourself. This book provides a sound basis for tackling physics experiments in the first couple of years of a university course. It concentrates on generic aspects of physics experimentation: planning for an experiment, keeping records of what you do, estimating uncertainties in measurements, analysing data numerically and graphically, and producing a written report.

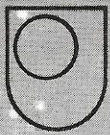
This practical handbook is used in the Open University course SXR207 *Physics by Experiment*. The course includes a one-week residential school on a university campus, where students work on a range of physics experiments and practise the skills introduced in this book. The course complements the Open University course S207 *The Physical World*, which provides a wide-ranging introduction to university-level physics.



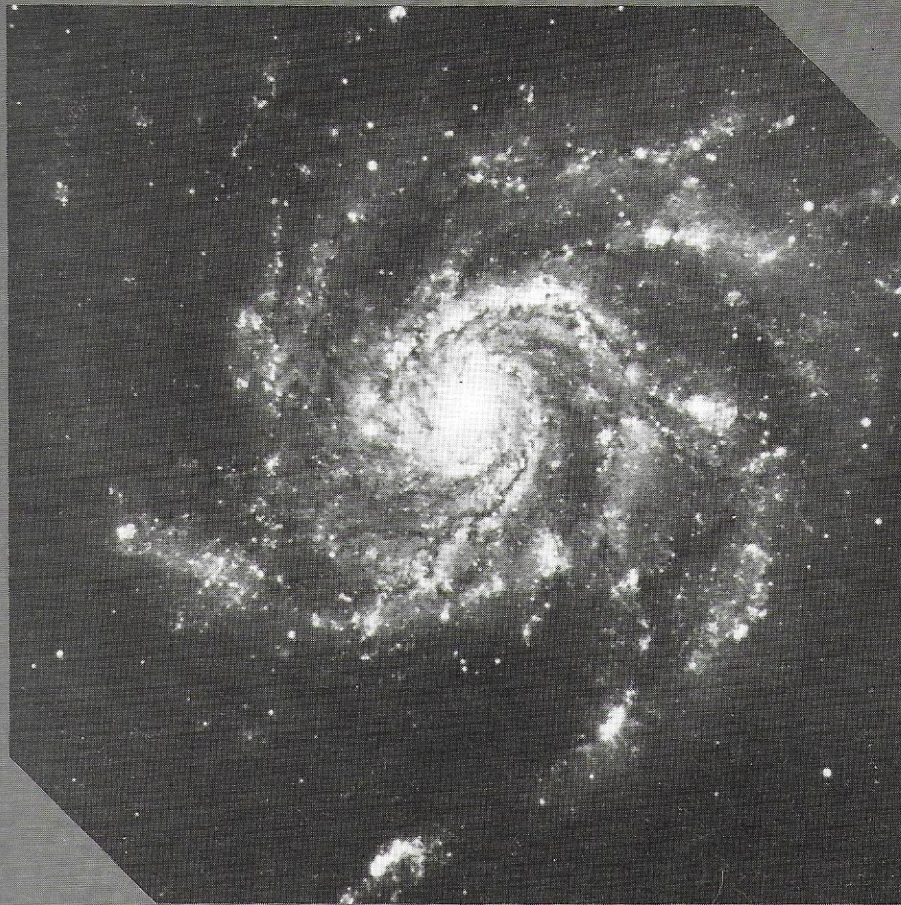
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SXR207 A practical handbook

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S256 MATTER IN THE UNIVERSE



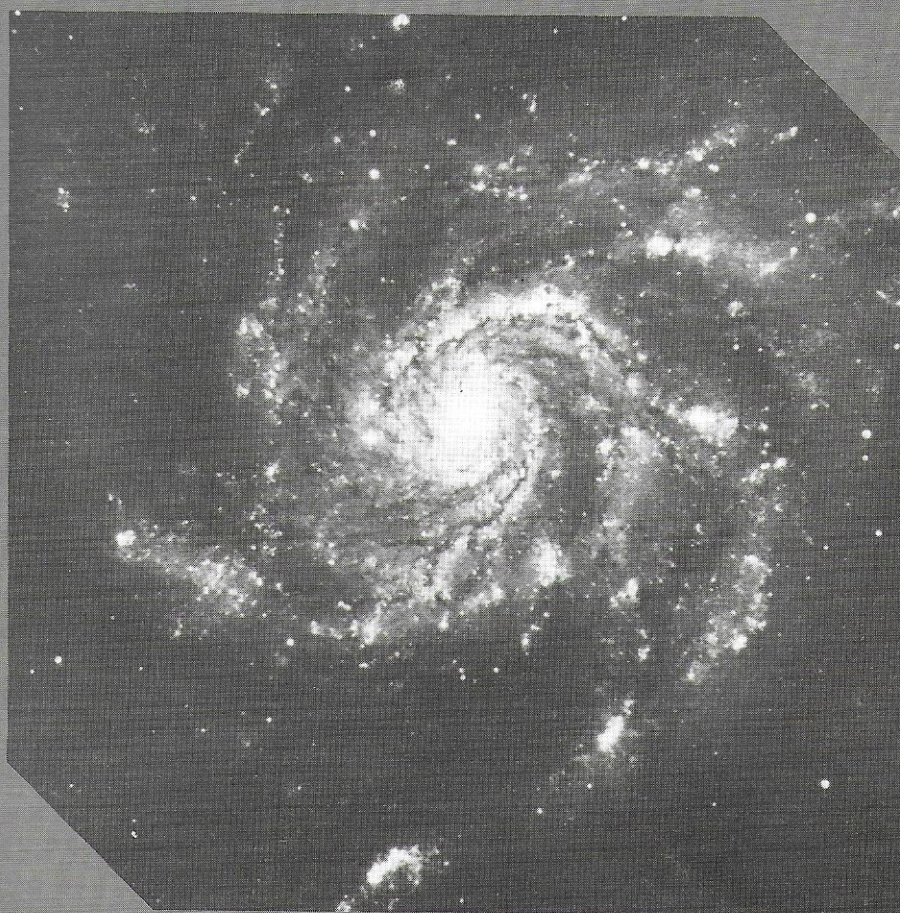
1

Setting the Scene



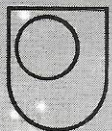
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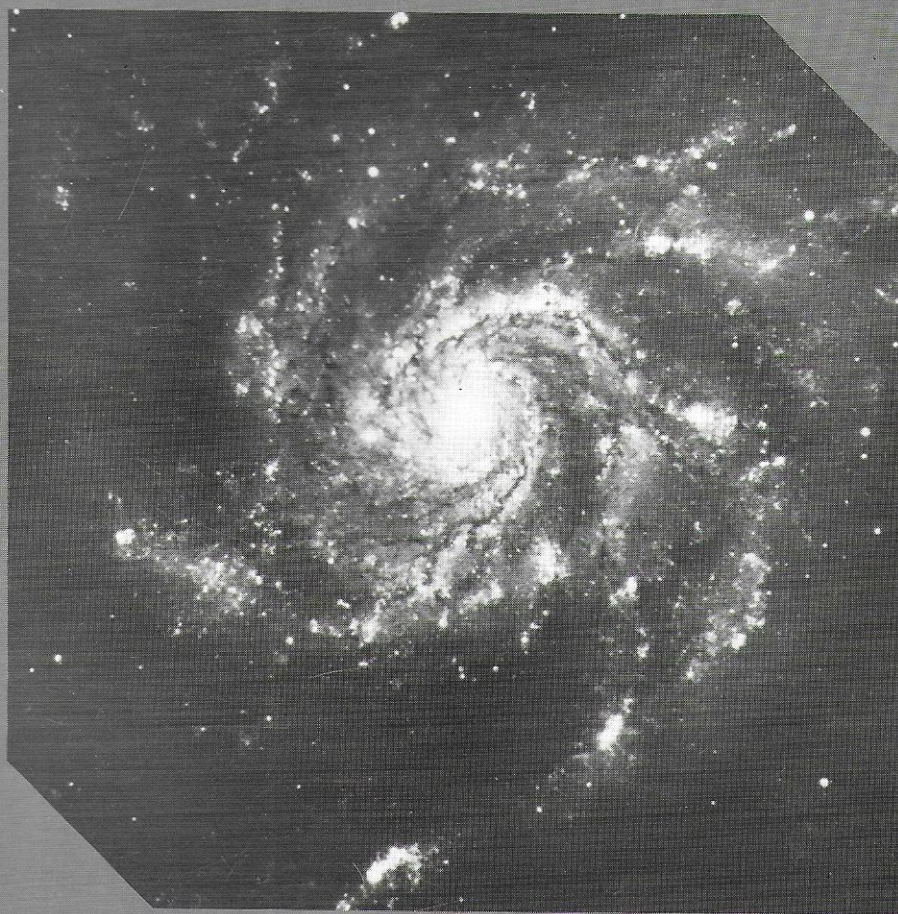
2

**Observing the
Interstellar Medium**



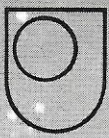
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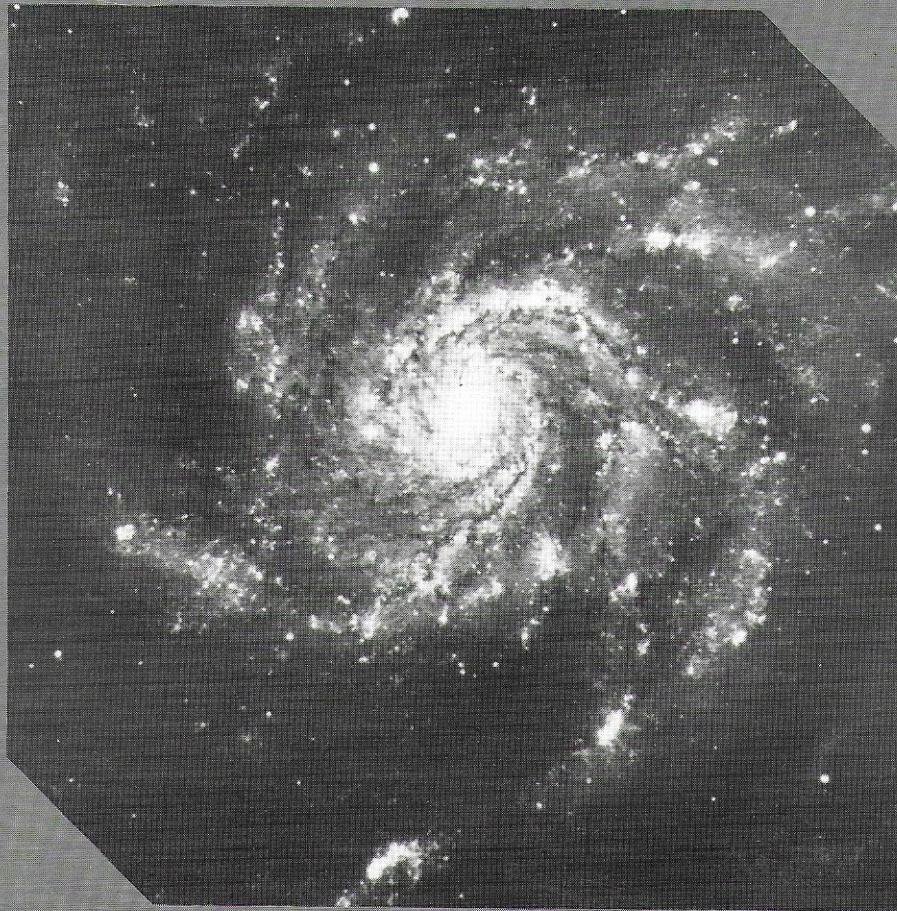


3

**Physics and
Chemistry of the
Interstellar Medium**

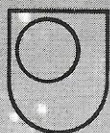


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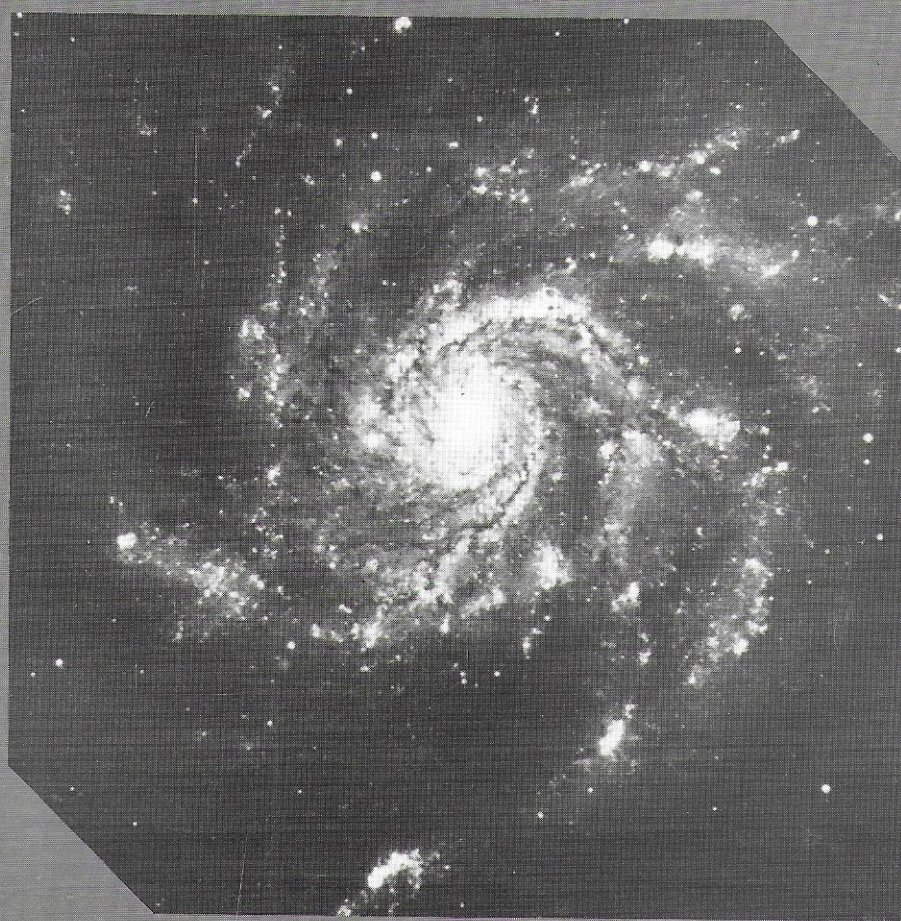


4

Observing the Stars

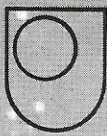


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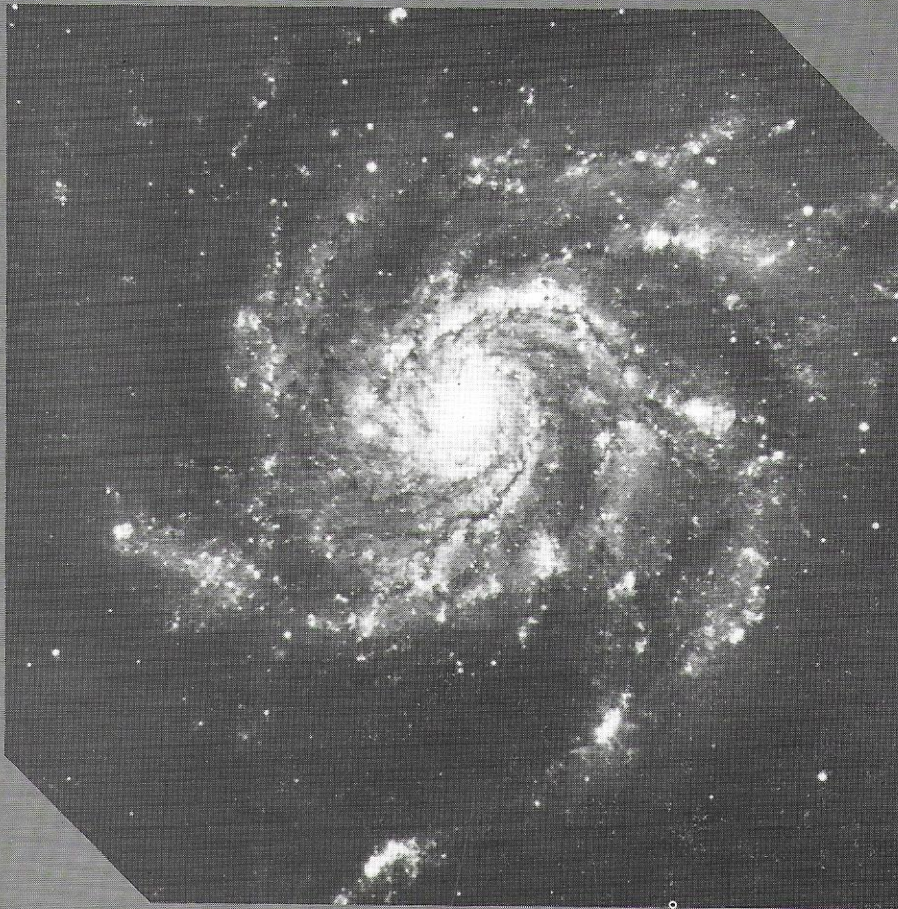


5

**The Formation
and Evolution
of the Stars**

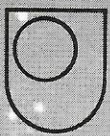


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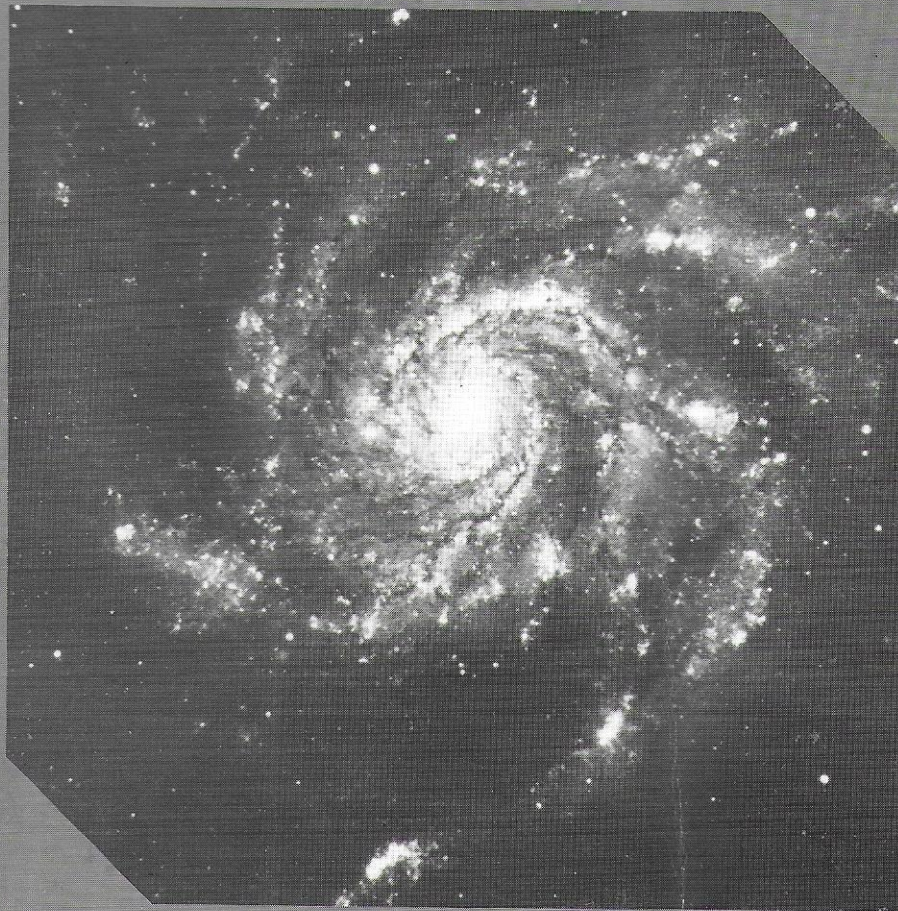


6

**Galaxies
and the Universe**

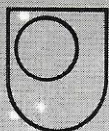


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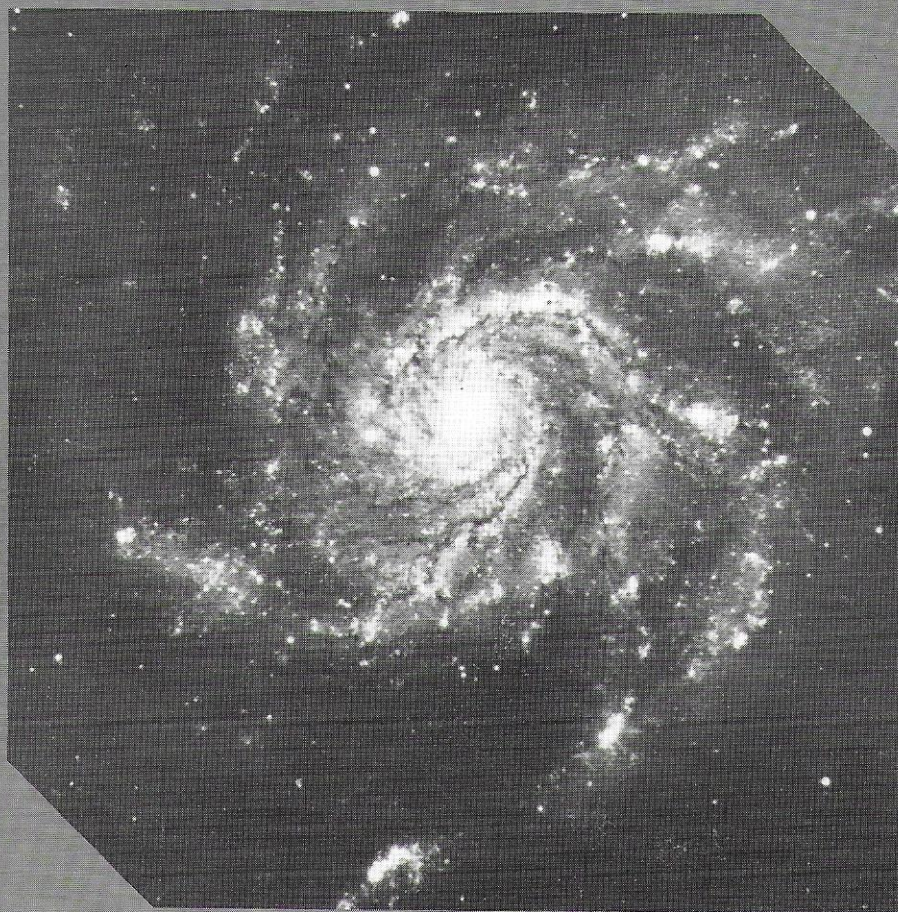


7

The Solar System



S256 MATTER IN THE UNIVERSE



8 The Origin and
Evolution of
Planetary Systems

Quantities used in S256

symbol	quantity	working value
c	speed of light	$3.00 \times 10^8 \text{ m s}^{-1}$
h	Planck constant	$6.63 \times 10^{-34} \text{ J s}$
k	Boltzmann constant	$1.38 \times 10^{-23} \text{ J K}^{-1}$
G	gravitational constant	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
R	molar gas constant	$8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
N_A	Avogadro constant	$6.02 \times 10^{23} \text{ mol}^{-1}$
σ	Stefan constant	$5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
ϵ_0	permittivity of vacuum	$8.85 \times 10^{-12} \text{ F m}^{-1}$
e	elementary charge	$1.60 \times 10^{-19} \text{ C}$
m_p	mass of proton	$1.672649 \times 10^{-27} \text{ kg}$
m_n	mass of neutron	$1.674954 \times 10^{-27} \text{ kg}$
m_e	mass of electron	$9.11 \times 10^{-31} \text{ kg}$ (or $0.511 \text{ MeV}/c^2$)
m_H	mass of hydrogen atom (factor used to convert relative molecular mass to mass in kg)	$1.67 \times 10^{-27} \text{ kg}$
M_E	mass of the Earth	$5.98 \times 10^{24} \text{ kg}$
$M_\odot$	solar mass	$1.99 \times 10^{30} \text{ kg}$
$R_\odot$	solar radius	$6.96 \times 10^8 \text{ m}$
$L_\odot$	solar luminosity	$3.83 \times 10^{26} \text{ W}$
$T_{e\odot}$	solar effective temperature	5770 K
	age of the Galaxy	$\simeq 1.2 \times 10^{10} \text{ years}$
	age of the Universe	$\simeq 1.5 \times 10^{10} \text{ years}$
	age of the Sun and Solar System	$\simeq 4.6 \times 10^9 \text{ years}$
	Neptune orbit, semi-major axis	30.1 AU
AU	astronomical unit	$1.50 \times 10^{11} \text{ m}$
ly	lightyear	$9.46 \times 10^{15} \text{ m}$
pc	parsec	$3.09 \times 10^{16} \text{ m}$

Useful conversions

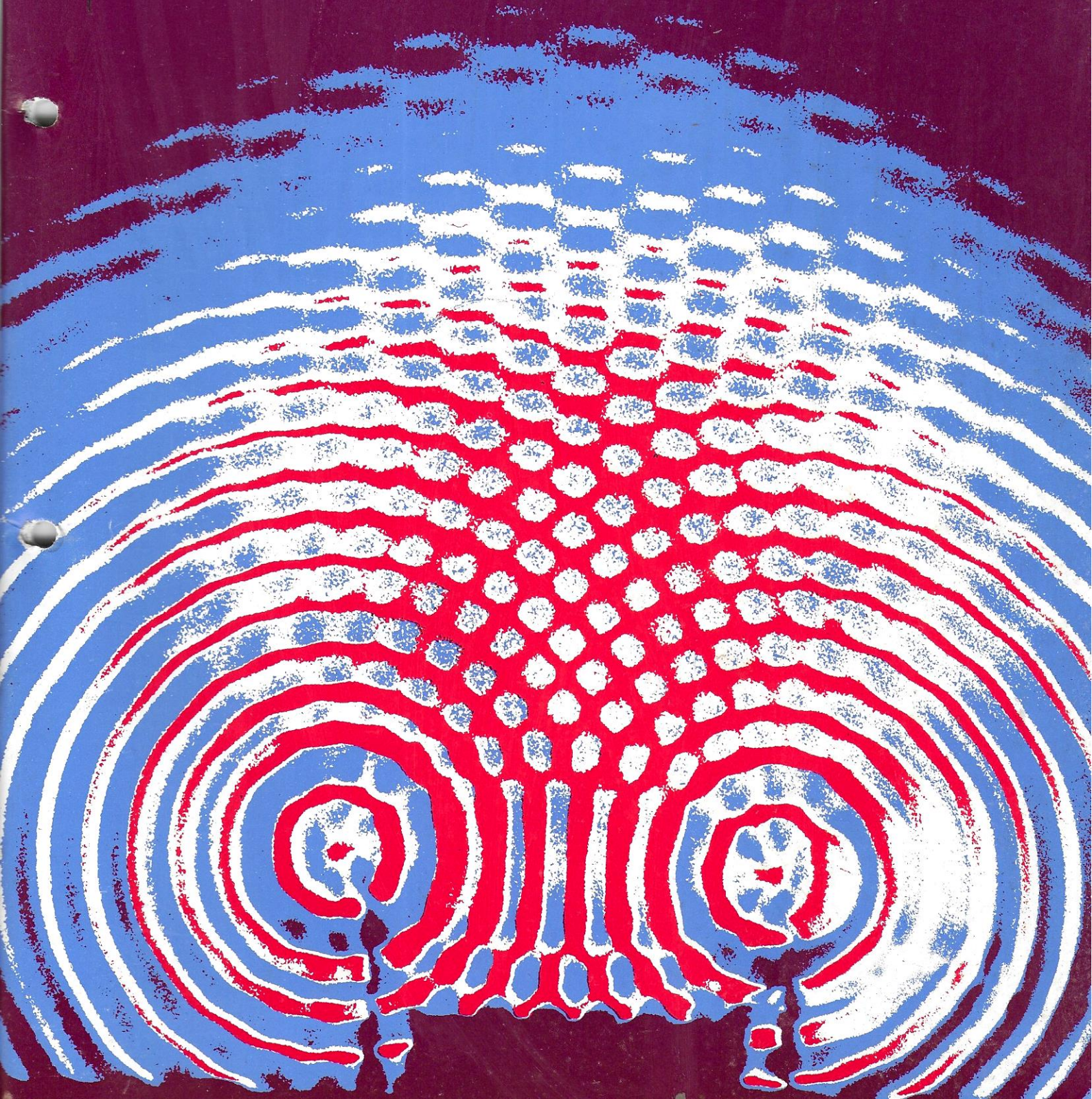
1 electronvolt (eV) = 1.602×10^{-19} joules (J)
 1 year = 3.156×10^7 seconds
 1 degree = $(\pi/180)$ radians = 60 arcmin = 3 600 arcsec
 1 radian = $(180/\pi)$ degrees = 206 265 arcsec

unit	m	AU	ly	pc
1 m =	1	6.68×10^{-12}	1.06×10^{-16}	3.24×10^{-17}
1 AU =	1.50×10^{11}	1	1.58×10^{-5}	4.85×10^{-6}
1 ly =	9.46×10^{15}	6.32×10^4	1	0.307
1 pc =	3.09×10^{16}	2.06×10^5	3.26	1
1 kpc =	3.09×10^{19}	2.06×10^8	3.26×10^3	10^3
1 Mpc =	3.09×10^{22}	2.06×10^{11}	3.26×10^6	10^6

The cover photograph is of the spiral galaxy, M101 (NGC 5457) in Ursa Major.
 Photo Palomar Observatory.

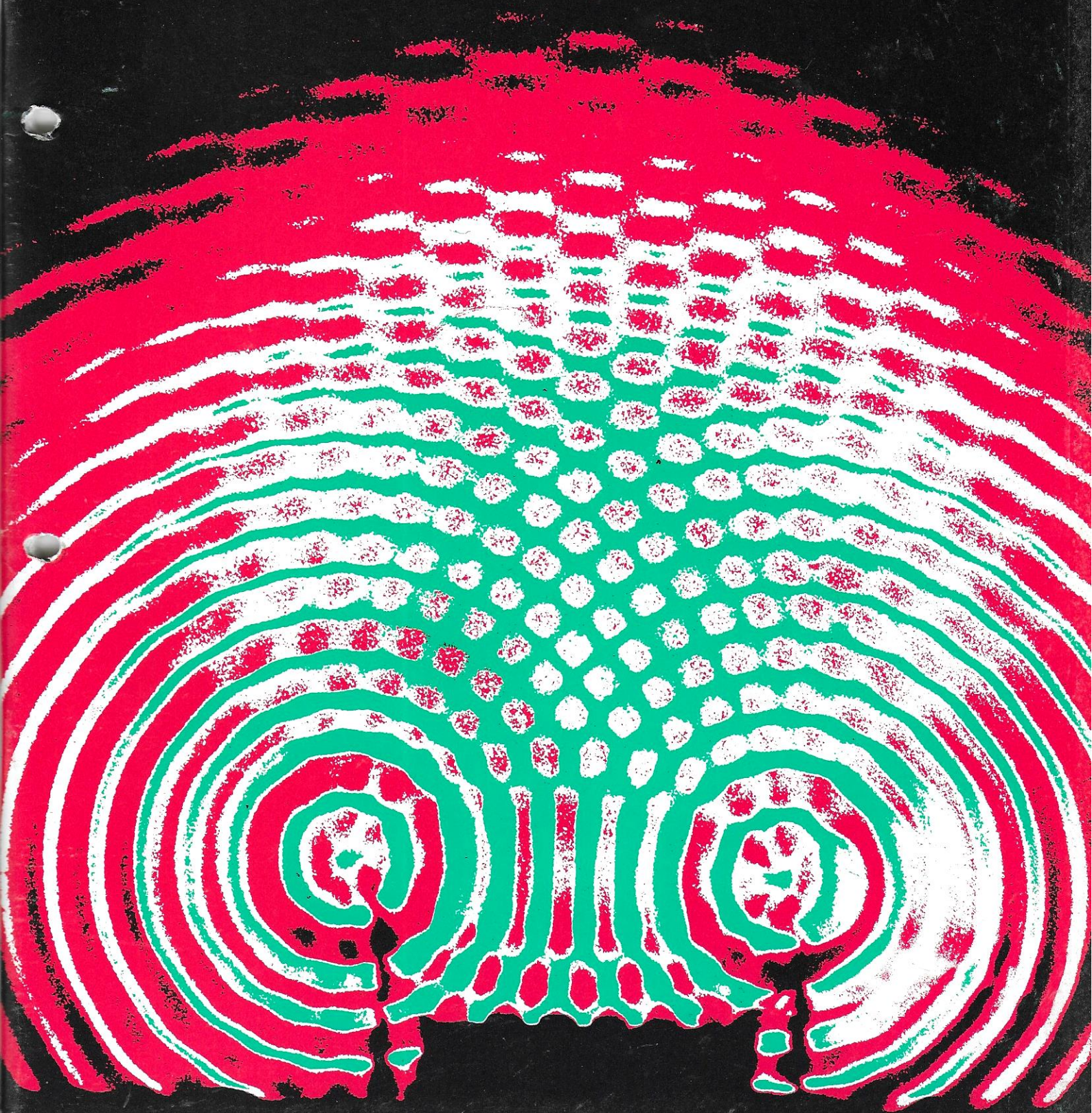


1 Surveying the Universe: an example of physical enquiry



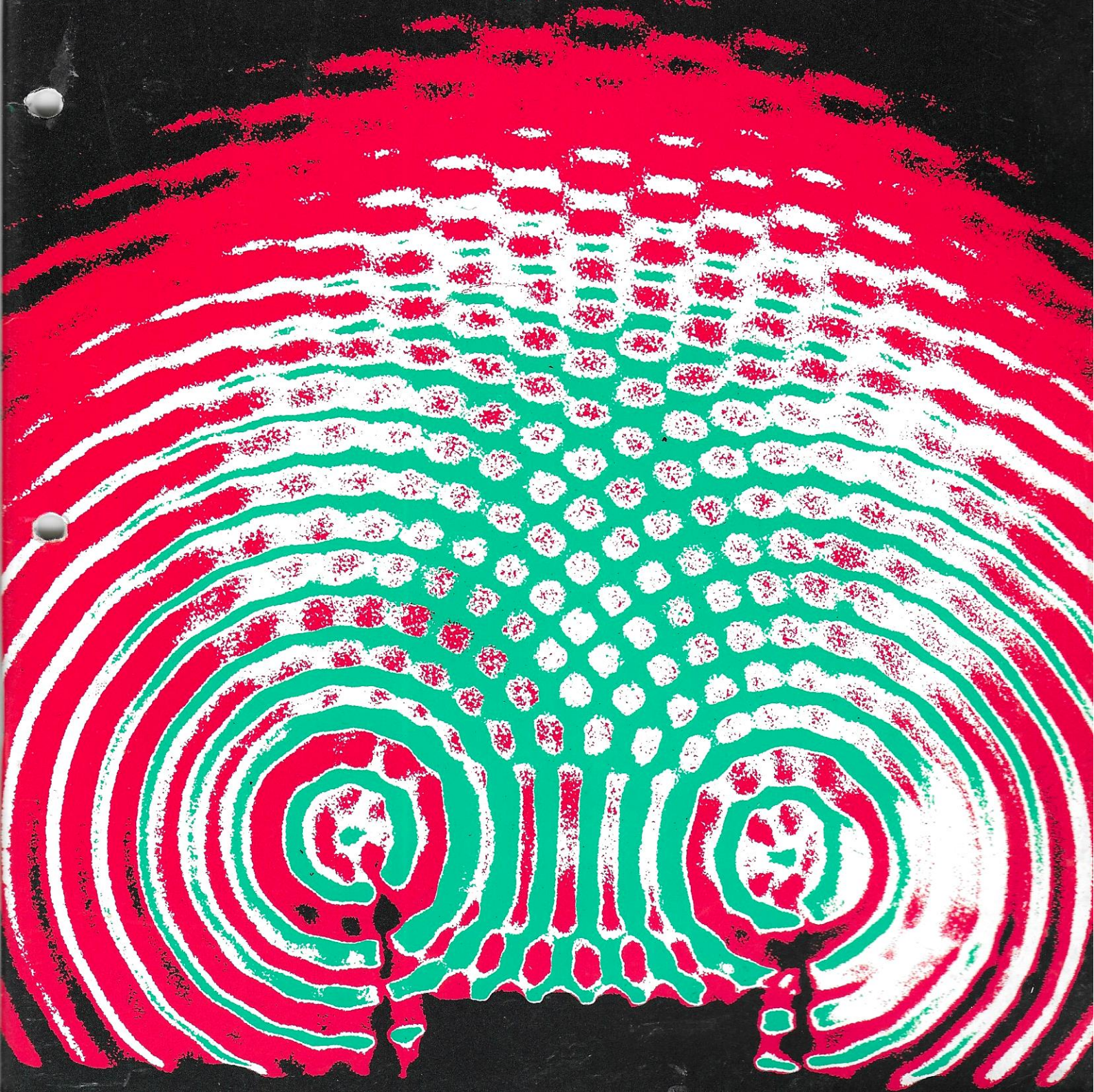


2 Describing motion





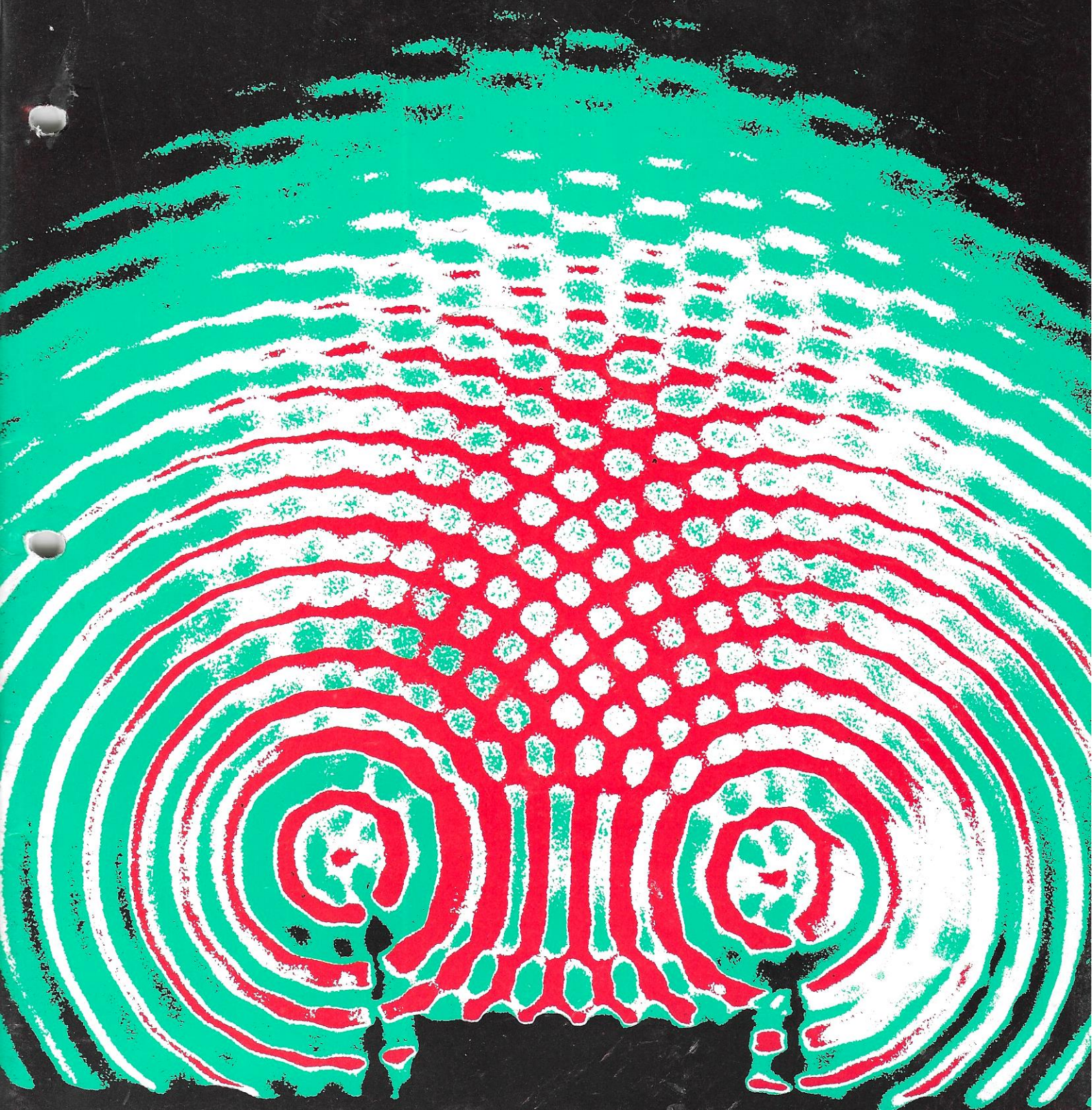
3 Dynamics—forces, energy and motion





4 Equilibrium, stability and gravitation

5 Mechanics revision





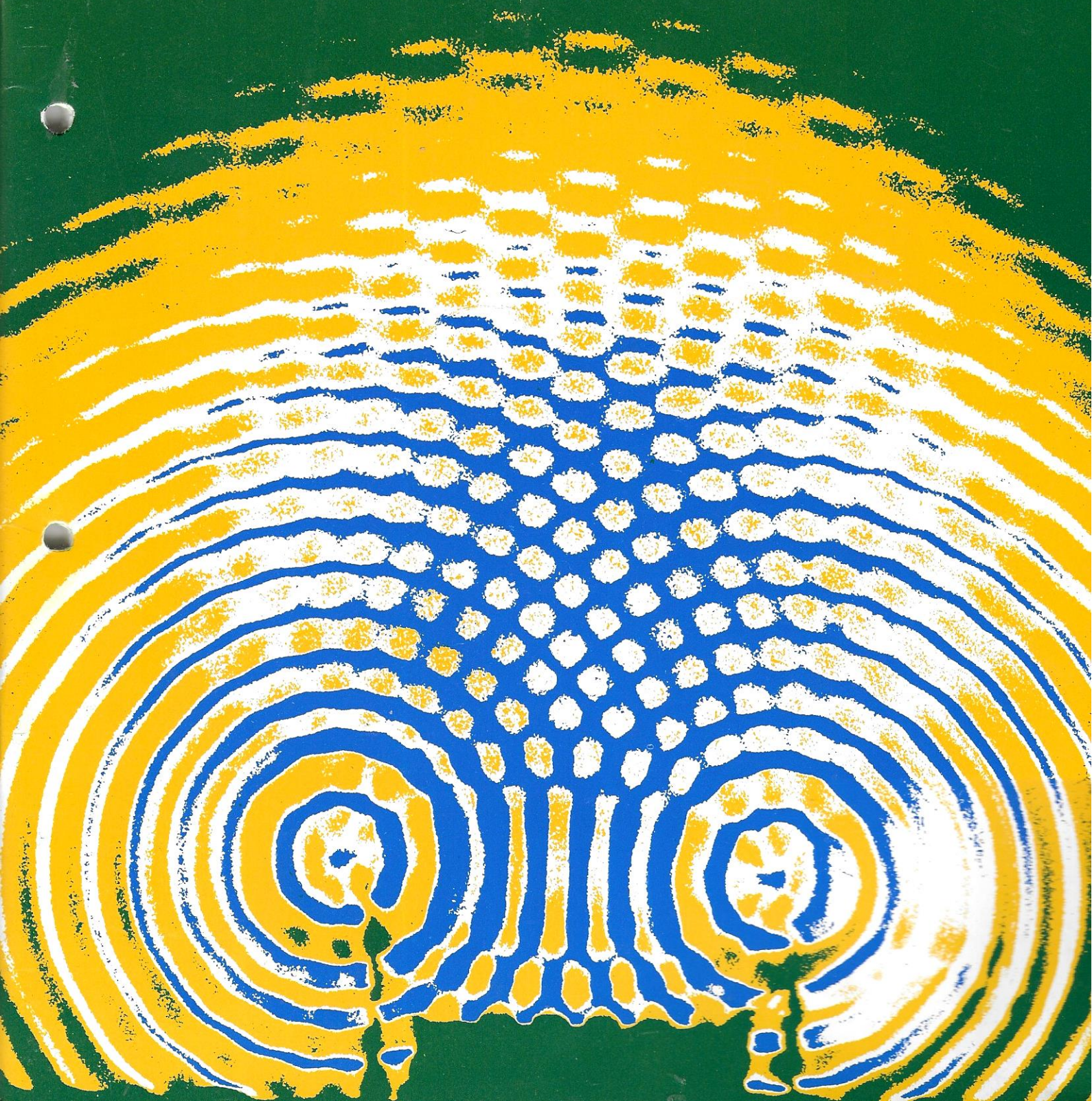
6 Electrostatics





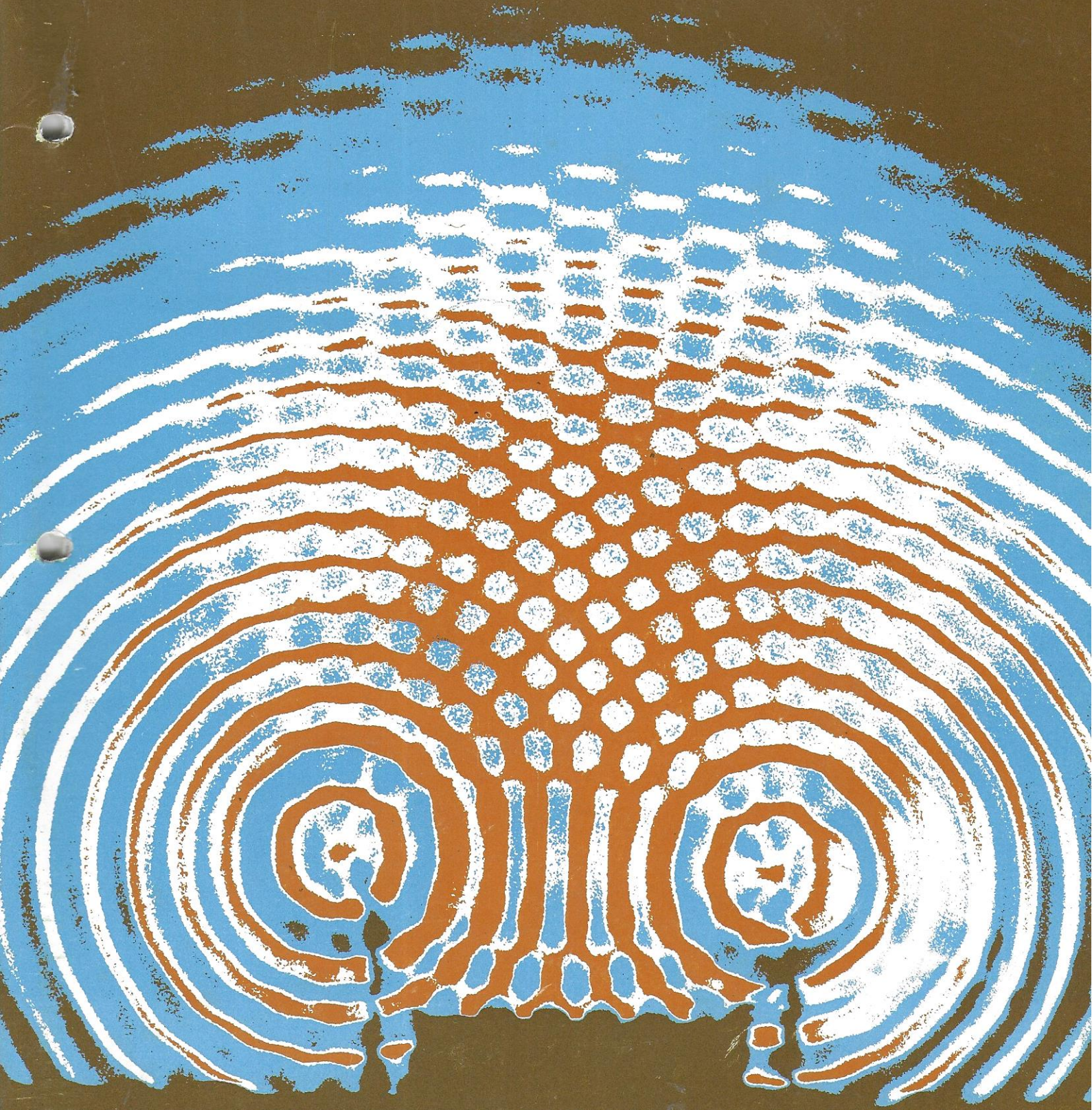
7 Currents and circuits

8 Electrodynamics



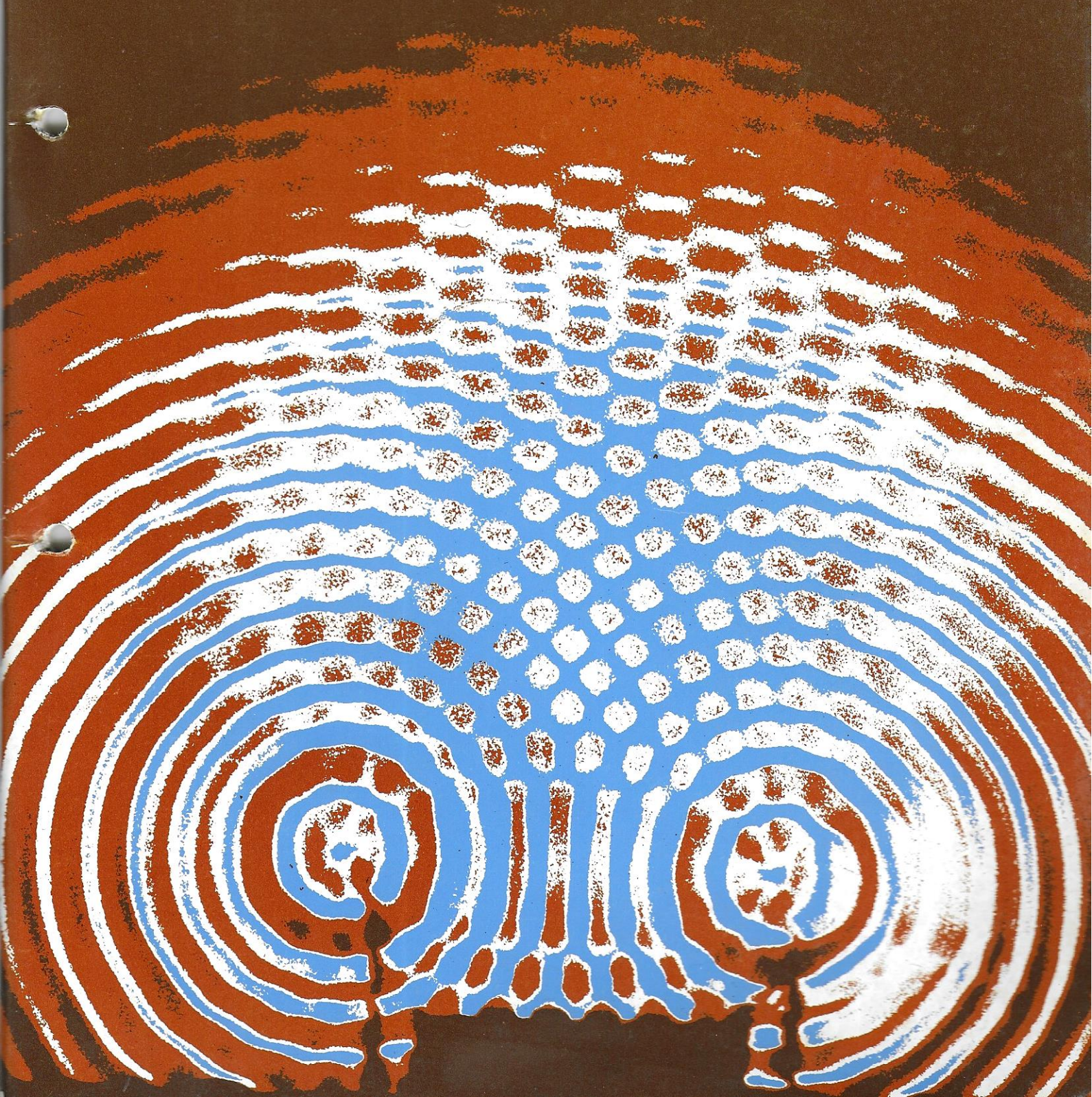


9&10 Vibrations and waves



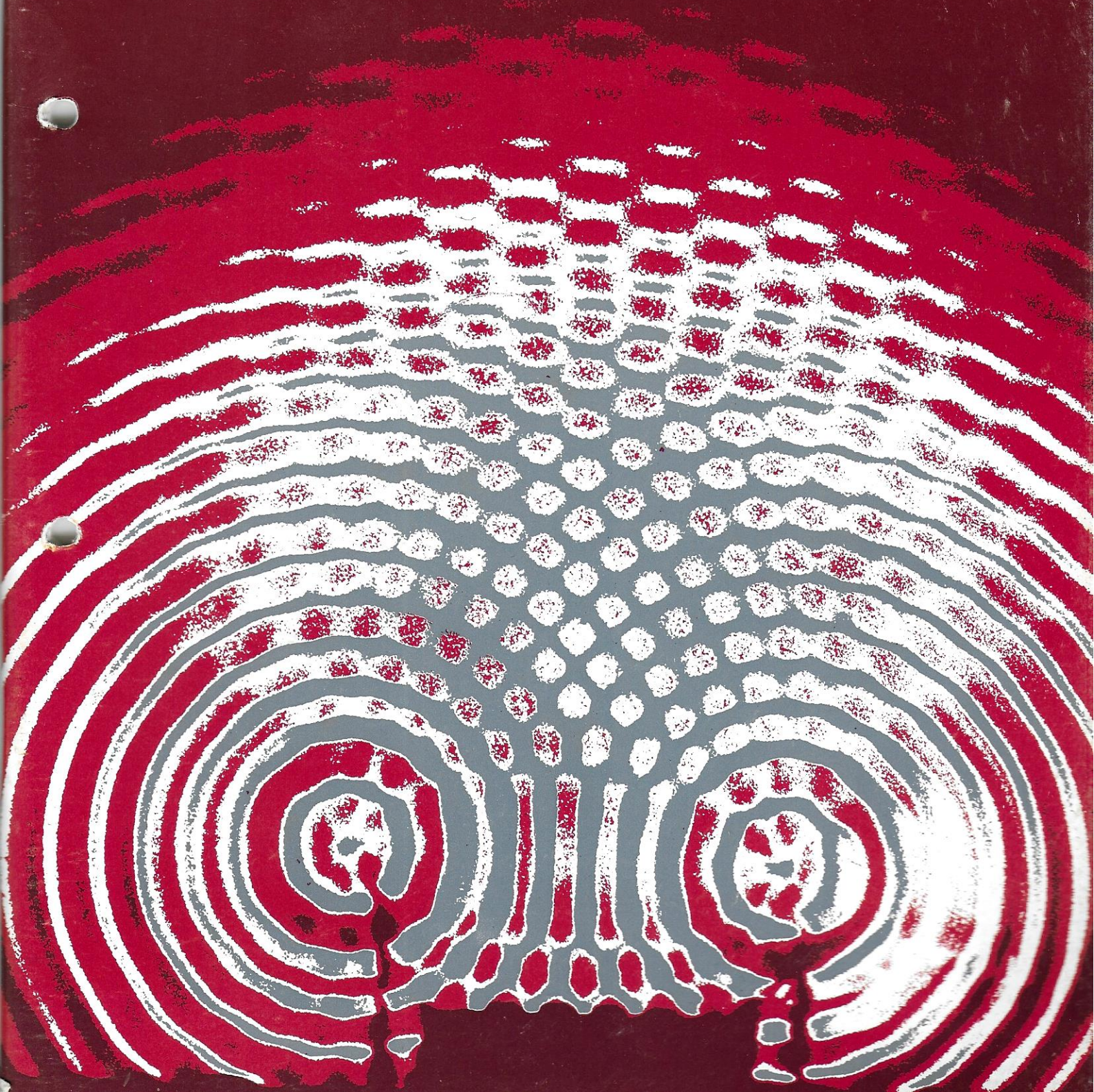


11 Temperature and heat: towards a microscopic explanation



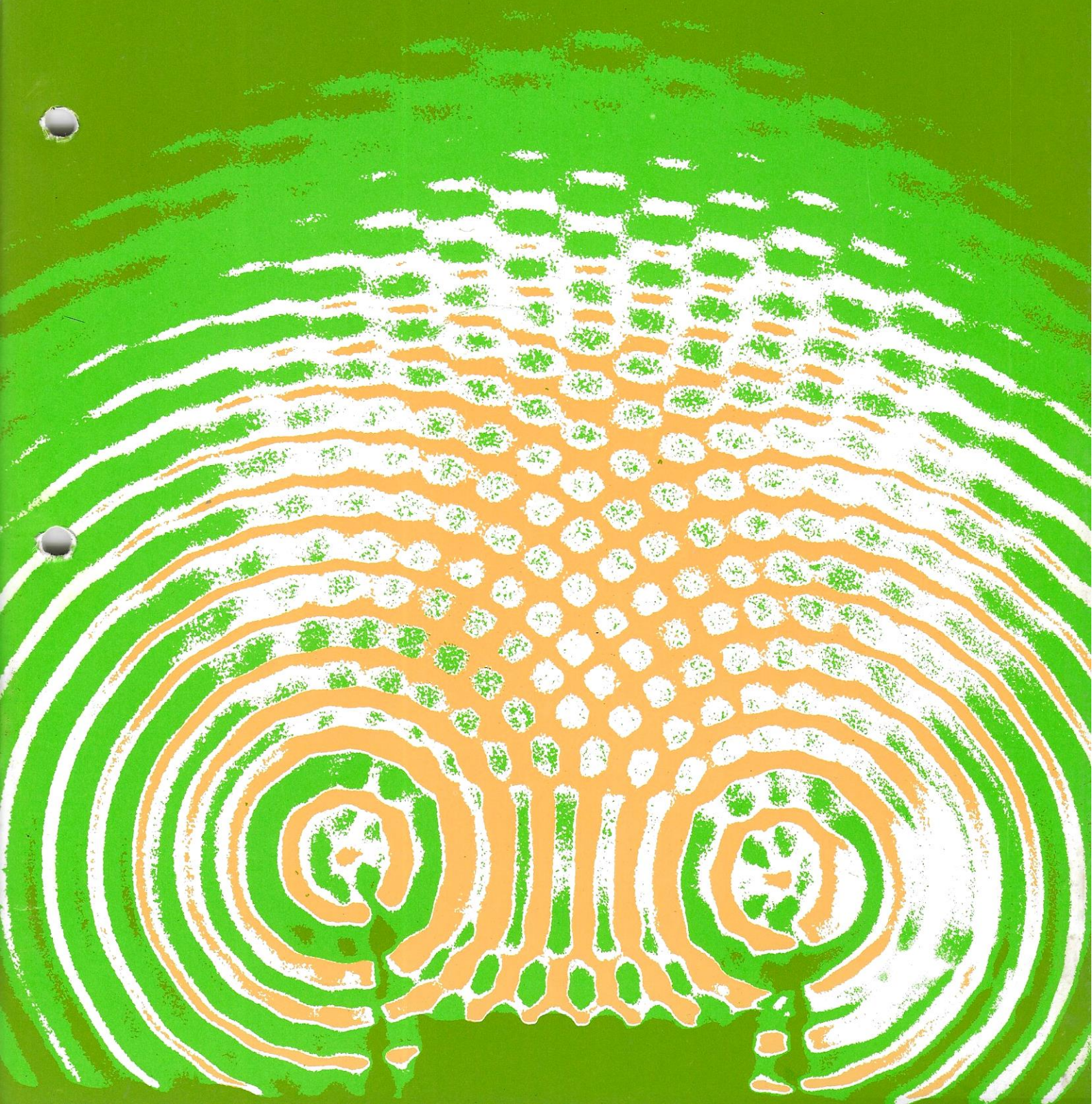


12 Special relativity



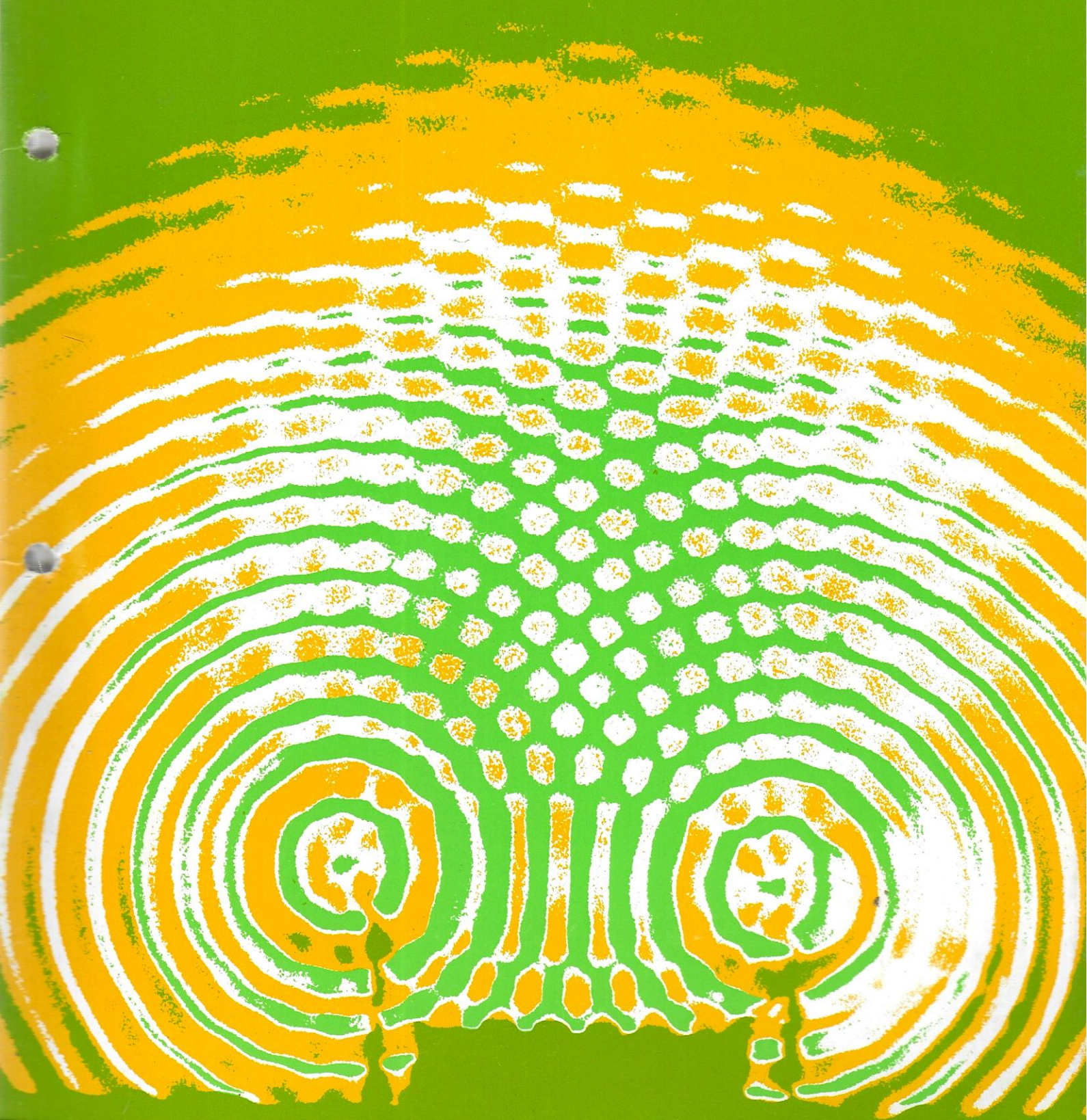


13 The beginnings of modern atomic physics



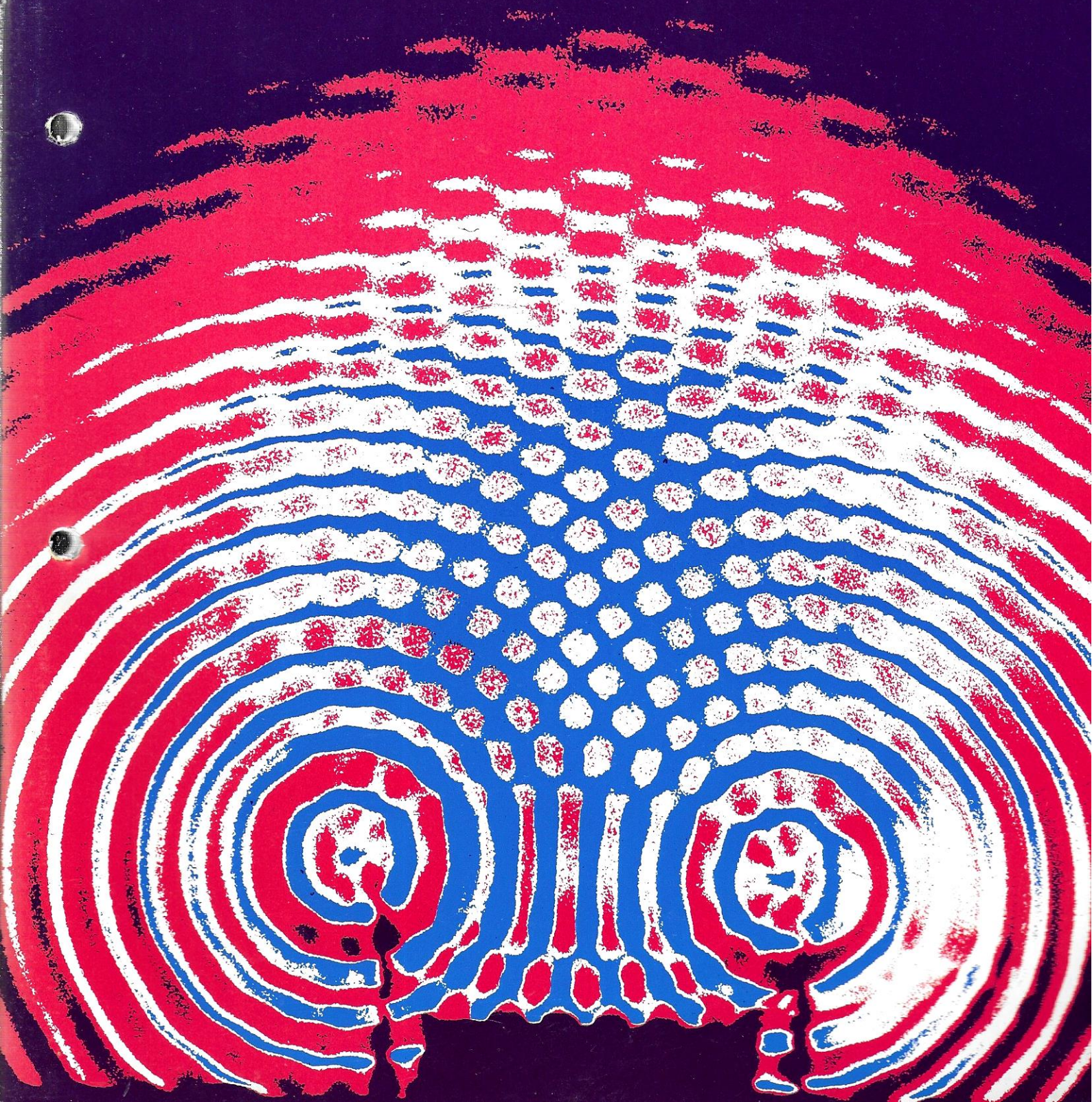


14 & 15 Quantum mechanics: theory and applications





16 Modern physics in dying stars



Fundamental constants used in S271

Symbol	Quantity	Value
c	speed of light in vacuum	$2.998 \times 10^8 \text{ m s}^{-1}$
μ_0	permeability of free space	$4\pi \times 10^{-7} \text{ T m A}^{-1}$
ϵ_0	permittivity of free space	$8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
$1/4\pi\epsilon_0$		$8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
e	charge of the proton	$1.602 \times 10^{-19} \text{ C}$
$-e$	charge of the electron	$-1.602 \times 10^{-19} \text{ C}$
h	Planck constant	$6.626 \times 10^{-34} \text{ J s}$
$\hbar$	$h/2\pi$	$1.055 \times 10^{-34} \text{ J s}$
m_e	electron rest mass	$9.109 \times 10^{-31} \text{ kg}$
$m_e c^2$	electron rest energy	$8.187 \times 10^{-14} \text{ J, or } 5.110 \times 10^{-1} \text{ MeV}$
$-e/m_e$	electron charge : mass ratio	$-1.759 \times 10^{11} \text{ C kg}^{-1}$
m_p	proton rest mass	$1.673 \times 10^{-27} \text{ kg}$
m_n	neutron rest mass	$1.675 \times 10^{-27} \text{ kg}$
R	Rydberg constant	$1.097 \times 10^7 \text{ m}^{-1}$
a_0	Bohr radius	$5.292 \times 10^{-11} \text{ m}$
N_A	Avogadro constant	$6.022 \times 10^{23} \text{ mol}^{-1}$
R	molar gas constant	$8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
k	Boltzmann constant	$1.381 \times 10^{-23} \text{ J K}^{-1}$
G	gravitational constant	$6.673 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

Main units used in S271

Quantity	SI unit	Symbol	Quantity	SI unit	Symbol
length	metre	m	power	watt	W
mass	kilogram	kg	electric charge	coulomb	C
time	second	s	potential difference	volt	V
frequency	hertz	Hz	resistance	ohm	Ω
electric current	ampere	A	capacitance	farad	F
temperature	kelvin	K	inductance	henry	H
energy	joule	J	magnetic field	tesla	T
force	newton	N			

Useful conversions

1 mile = 1.609 km	1 kilocalorie = 4 187 J
1 U.K. gallon (gal) = $4.546 \times 10^{-3} \text{ m}^3$	1 electronvolt (eV) = $1.602 \times 10^{-19} \text{ J}$
1 pound (lb) = $4.536 \times 10^{-1} \text{ kg}$	1 kilowatt hour (kW h) = $3.600 \times 10^6 \text{ J}$
1 tonne = 1 000 kg	1 horsepower (hp) = $7.457 \times 10^2 \text{ W}$
1 year = $3.156 \times 10^7 \text{ s}$	1 degree = $(\pi/180) \text{ rad} = 3\,600 \text{ seconds of arc}$
1 atmosphere (atm) = $1.013 \times 10^5 \text{ N m}^{-2}$	

Prefixes for fractions and multiples of units

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d			
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	μ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f			



The physics of matter

Unit 1 Temperature, energy and the structure of matter

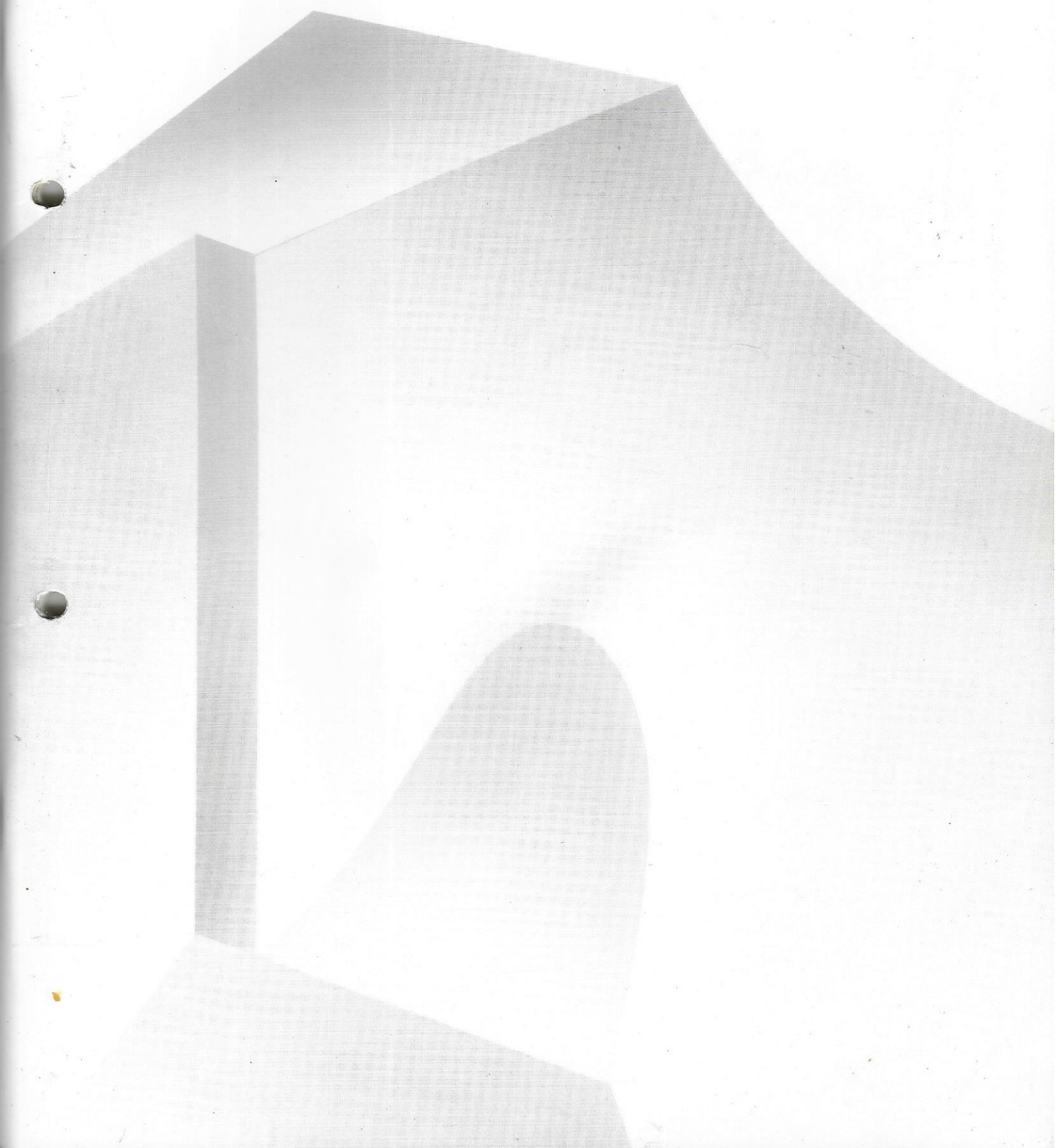




The physics of matter

Unit 2 Macroscopic descriptions of matter

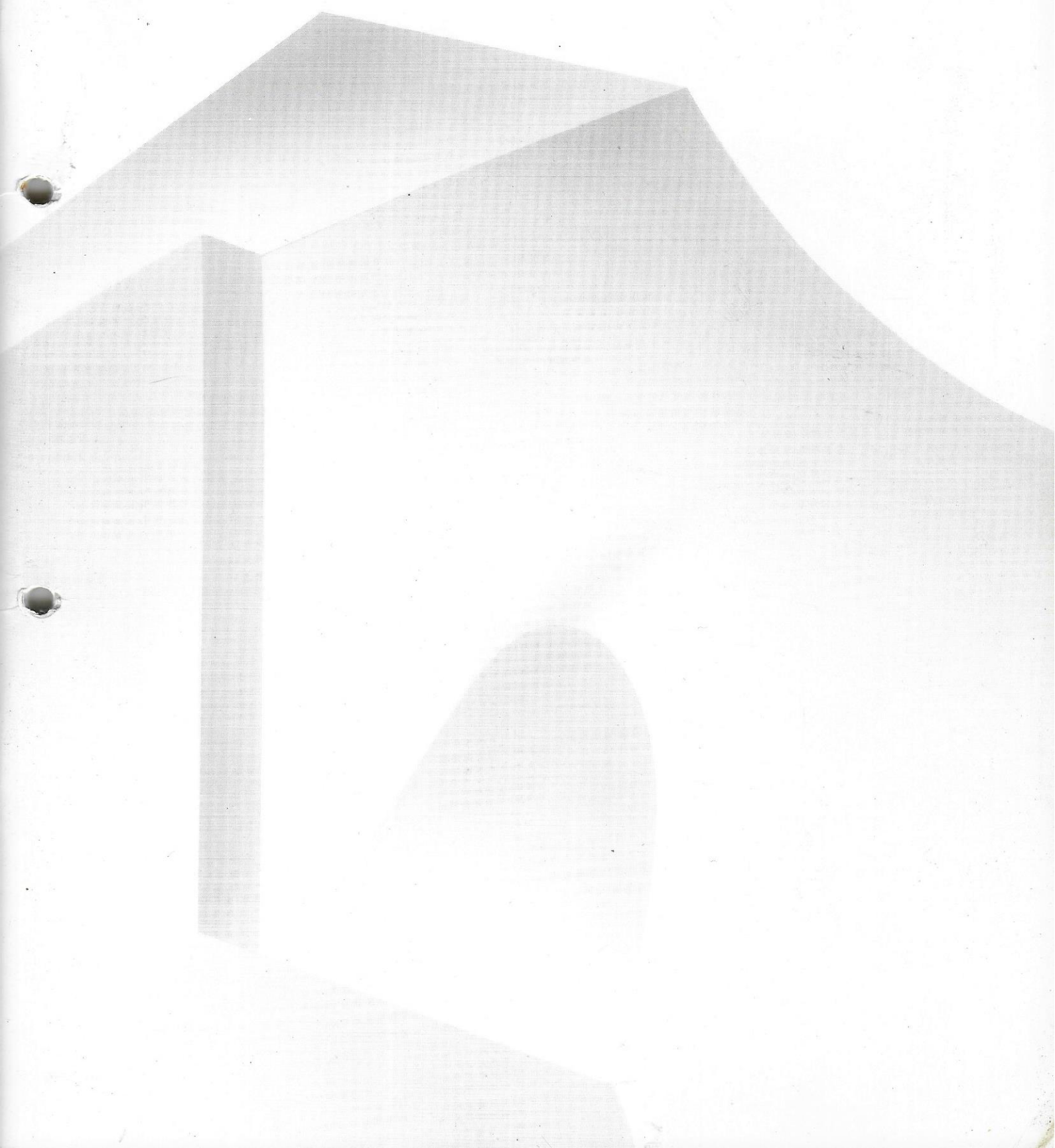
Unit 3 Microscopic models of matter





The physics of matter

**Unit 4 The Boltzmann factor – sharing
out the energy**
Unit 5 Block 1 revision and consolidation





The physics of matter

Unit 6 Equilibrium properties of gases

Unit 7 Transport properties of gases





The physics of matter

Unit 8 Quantum gases – photons and electrons





The physics of matter

Unit 9 The structure and bonding of solids





The physics of matter

Unit 10 Mechanical properties of solids

Unit 11 Thermal properties of solids

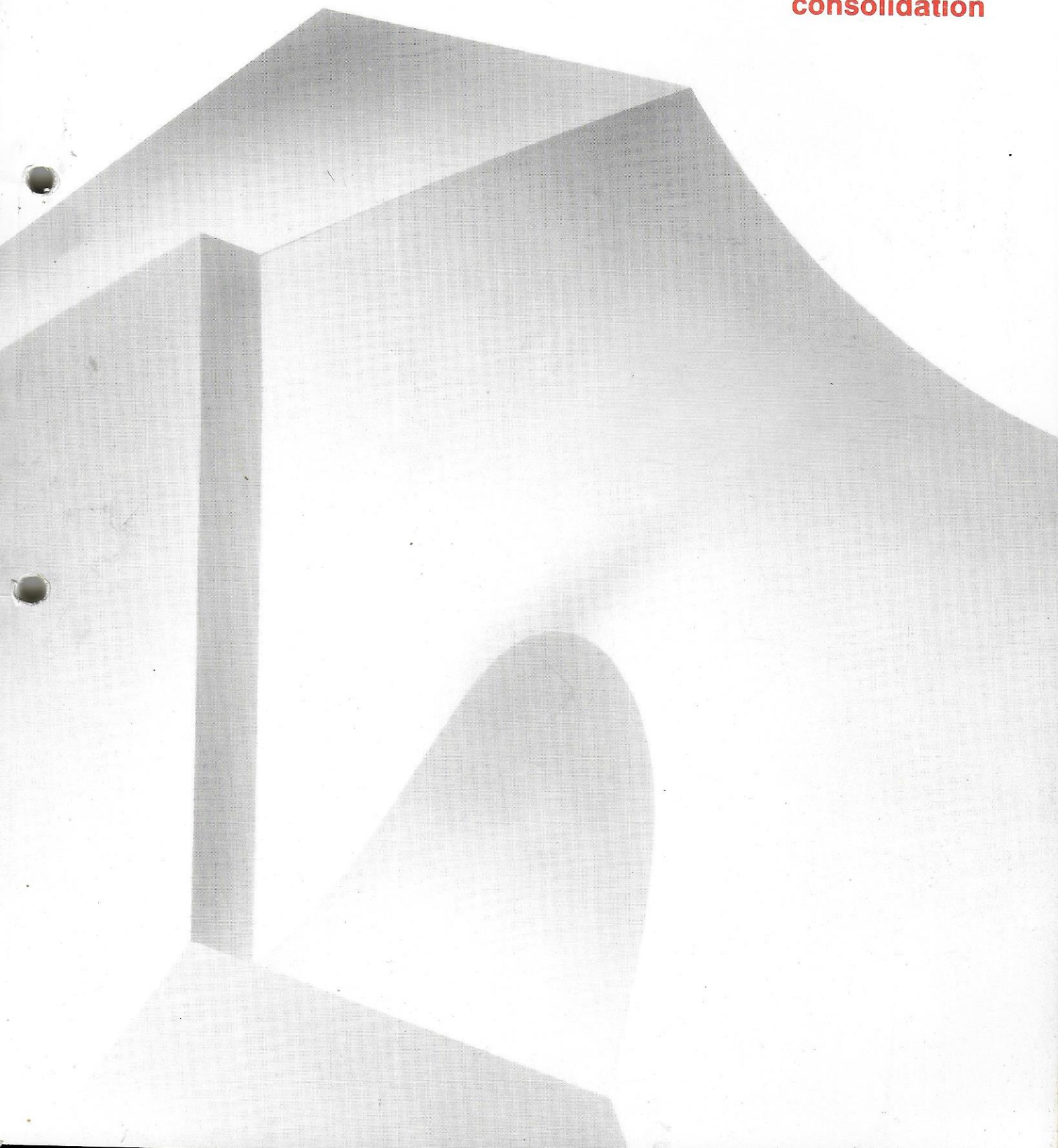




The physics of matter

**Units 12 and 13 Electrical properties of
solids**

**Unit 14 Block 3 revision and
consolidation**

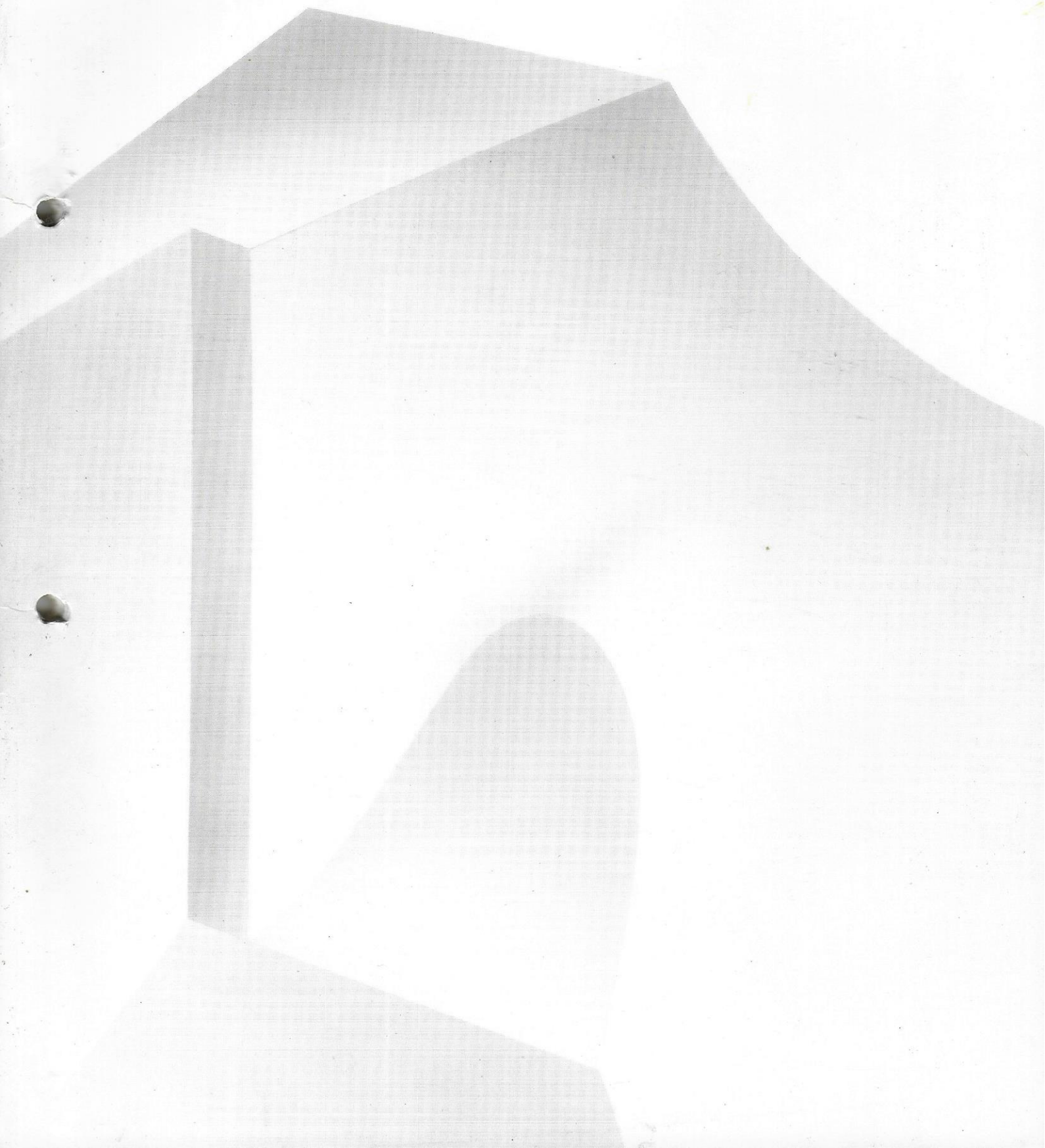




The physics of matter

Unit 15 Classical liquids

Unit 16 Superflow



Fundamental constants used in S272

Symbol	Quantity	Value
c	speed of light in vacuum	$2.998 \times 10^8 \text{ m s}^{-1}$
μ_0	permeability of free space	$4\pi \times 10^{-7} \text{ T m A}^{-1}$
ϵ_0	permittivity of free space	$8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
$1/4\pi\epsilon_0$		$8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
e	charge of the proton	$1.602 \times 10^{-19} \text{ C}$
$-e$	charge of the electron	$-1.602 \times 10^{-19} \text{ C}$
h	Planck constant	$6.626 \times 10^{-34} \text{ J s}$
$\hbar$	$h/2\pi$	$1.055 \times 10^{-34} \text{ J s}$
m_e	electron rest mass	$9.109 \times 10^{-31} \text{ kg}$
$m_e c^2$	electron rest energy	$8.187 \times 10^{-14} \text{ J}$
$-e/m_e$	electron charge: mass ratio	$-1.759 \times 10^{11} \text{ C kg}^{-1}$
m_p	proton rest mass	$1.673 \times 10^{-27} \text{ kg}$
m_n	neutron rest mass	$1.675 \times 10^{-27} \text{ kg}$
G	gravitational constant	$6.673 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
a_0	Bohr radius	$5.292 \times 10^{-11} \text{ m}$
N_m	Avogadro constant	$6.022 \times 10^{23} \text{ mol}^{-1}$
R	molar gas constant	$8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
k	Boltzmann constant	$1.381 \times 10^{-23} \text{ J K}^{-1}$
σ	Stefan constant	$5.669 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
μ_B	Bohr magneton	$9.274 \times 10^{-24} \text{ J T}^{-1}$
μ_N	nuclear magneton	$5.051 \times 10^{-27} \text{ J T}^{-1}$

Useful conversions

1 mile = 1.609 km	1 kilocalorie = 4187 J
1 U.K. gallon (gal) = $4.546 \times 10^{-3} \text{ m}^3$	1 electronvolt (eV) = $1.602 \times 10^{-19} \text{ J}$
1 pound (lb) = $4.536 \times 10^{-1} \text{ kg}$	1 kilowatt hour (kWh) = $3.600 \times 10^6 \text{ J}$
1 tonne = 1000 kg	1 horsepower (hp) = $7.457 \times 10^2 \text{ W}$
1 year = $3.156 \times 10^7 \text{ s}$	1 degree = $(\pi/180) \text{ rad}$ = 3600 seconds of arc
1 atmosphere (atm) = $1.013 \times 10^5 \text{ Pa}$	1 angstrom (Å) = 10^{-10} m
1 atomic mass unit (a.m.u.) = $1.661 \times 10^{-27} \text{ kg}$	

Round number estimates

room temperature (T_{room}) $\approx 295 \text{ K}$	$hf_{\text{visible}} \approx 2 \text{ eV}$
$kT_{\text{room}} \approx 0.025 \text{ eV}$	ultra-high vacuum $P \lesssim 10^{-6} \text{ Pa}$

Main units used in S272

Quantity	SI unit	Symbol	Quantity	SI unit	Symbol
length	metre	m	power	watt	W
mass	kilogram	kg	electric charge	coulomb	C
time	second	s	potential		
frequency	hertz	Hz	difference	volt	V
electric current	ampere	A	resistance	ohm	Ω
temperature	kelvin	K	capacitance	farad	F
energy	joule	J	inductance	henry	H
force	newton	N	magnetic field	tesla	T
pressure	pascal	Pa			

Prefixes for fractions and multiples of units

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10^2	hecto	h
10^{-2}	centi	c	10^3	kilo	k
10^{-3}	milli	m	10^6	mega	M
10^{-6}	micro	μ	10^9	giga	G
10^{-9}	nano	n	10^{12}	tera	T
10^{-12}	pico	p			
10^{-15}	femto	f			

S280 AA



SCIENCE MATTERS

Agriculture

edited by Pat Murphy

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SCIENCE MATTERS

Changing Climate

Kiki Warr and Sandy Smith

SCIENCE MATTERS

Discovering the Deep Oceans

Angela Colling

S280 GE



SCIENCE MATTERS

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*Norman Cohen and
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Jeff Thomas

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The Rise and Fall of Leaded Petrol

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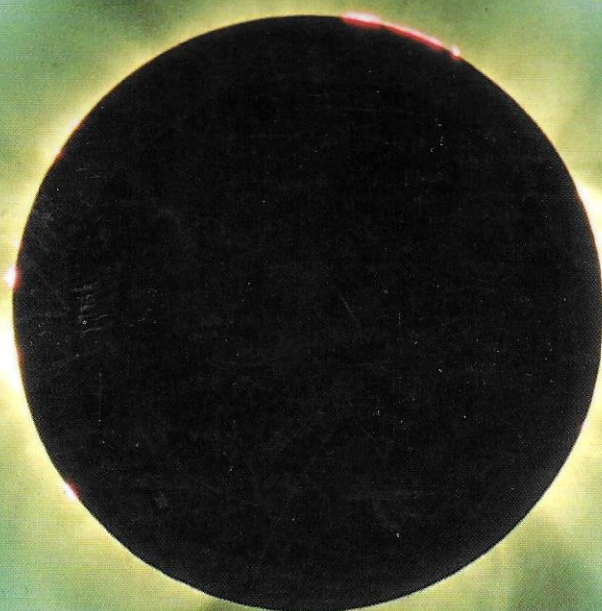
Nuclear Power

*Malcolm Scott and
David Johnson*



Science: a second level course

***Astronomy
and
Planetary Science***



***The Stars
and the
Interstellar Medium***



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The Planets

S281 Book 3



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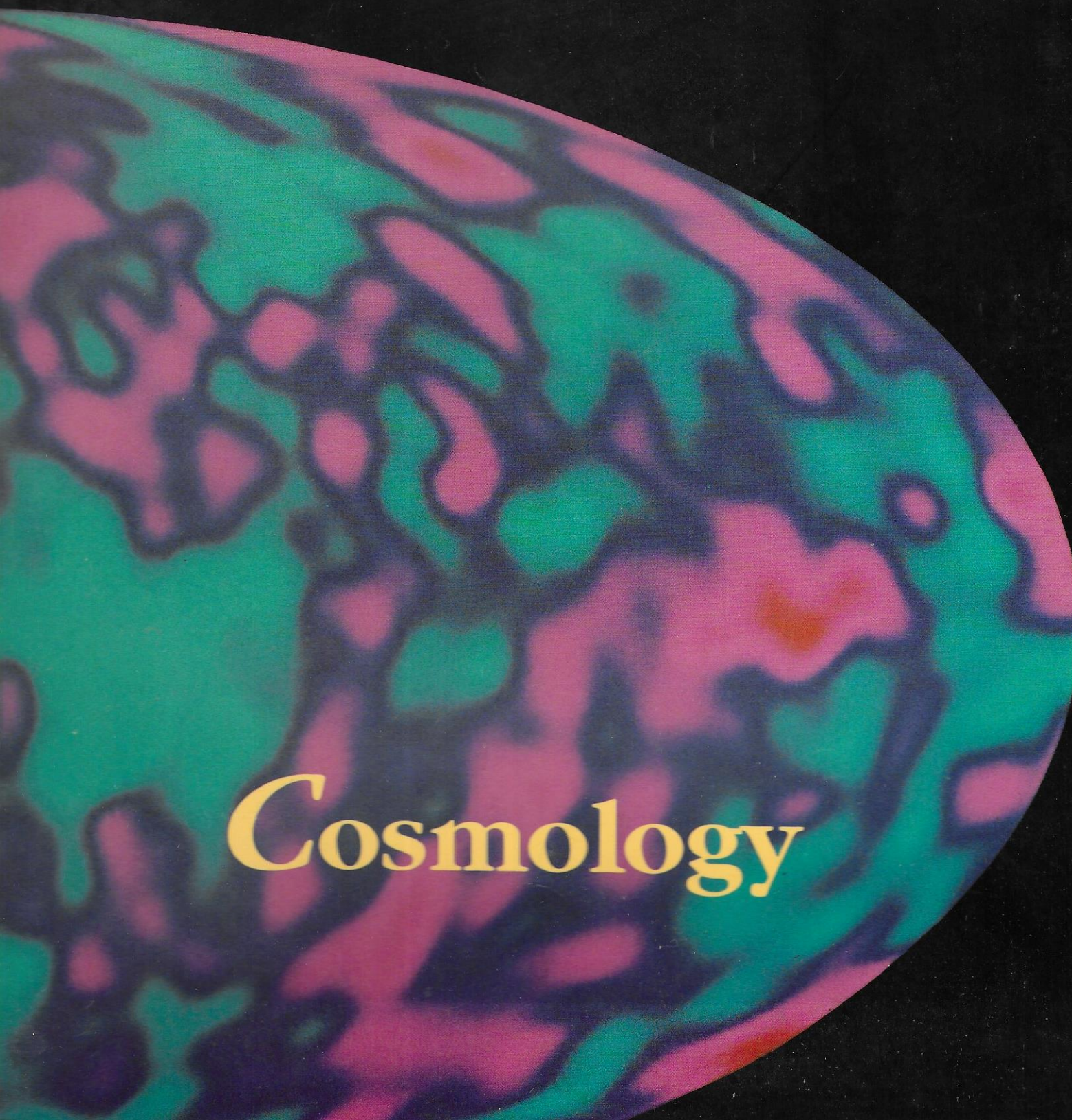
***Astronomy
and
Planetary Science***

Galaxies

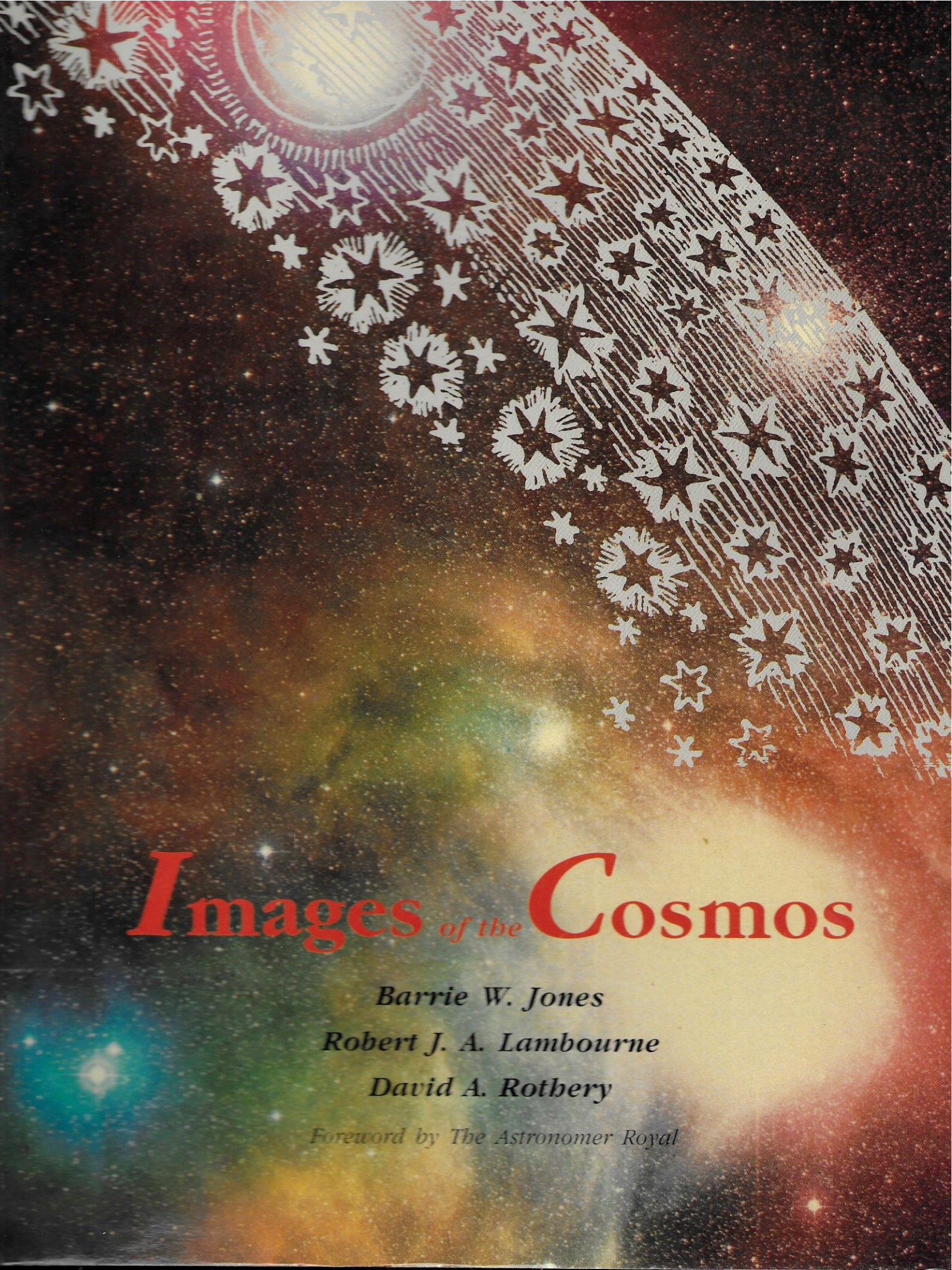


Science: a second level course

***Astronomy
and
Planetary Science***



Cosmology



Images of the *Cosmos*

Barrie W. Jones

Robert J. A. Lambourne

David A. Rothery

Foreword by The Astronomer Royal



This superb set of colourful images presents the planets, stars and galaxies in all their glory. Specially selected by a team of experts, they are arranged to tell a story that takes us from the Earth to the edge of the Universe, and back in time to the origin of everything. This tour of the cosmos features:

Recent images from the finest telescopes in the world and from the best craft that have ever been sent into space;
Images taken at wavelengths that are invisible to our eyes, revealing aspects of the cosmos that have hitherto been hidden from us;

Clear, concise explanations to accompany each image, including the size and distance of each celestial object shown.



S281 IC

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Hodder & Stoughton

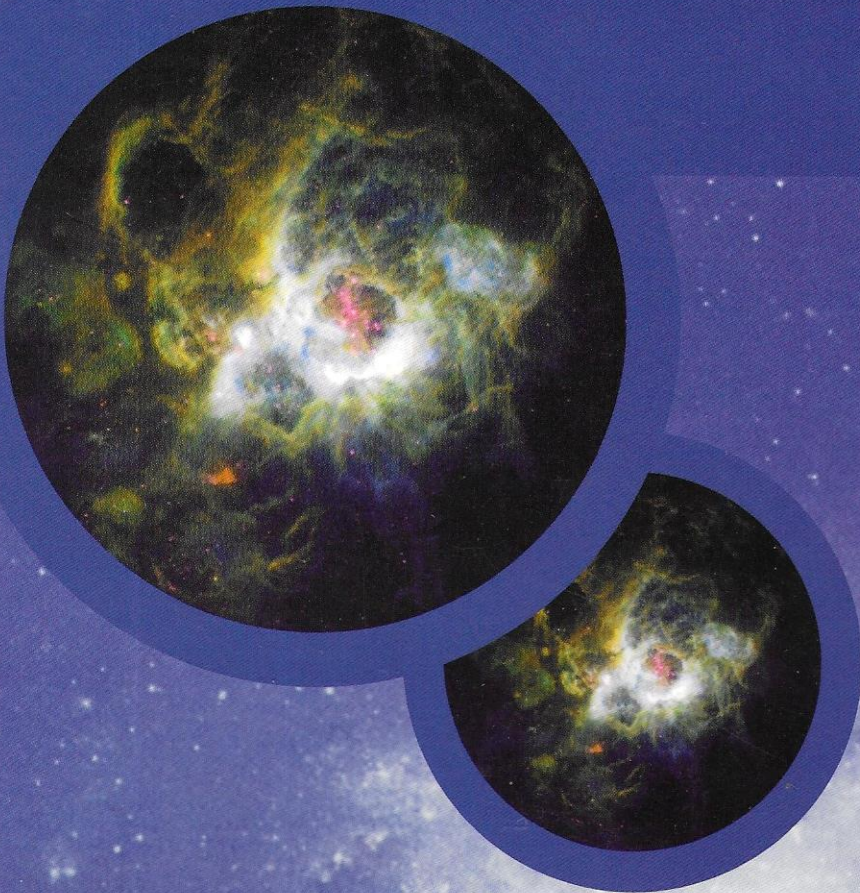


The Open
University

The Physics of Stars

SECOND
EDITION

A. C. Phillips



THE MANCHESTER PHYSICS SERIES

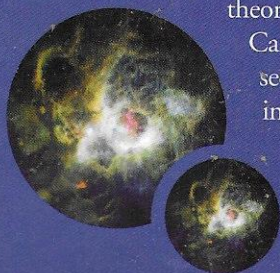
General Editors: D. J. SANDIFORD; F. MANDL; A. C. PHILLIPS
Department of Physics and Astronomy, University of Manchester

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STATISTICAL PHYSICS Second Edition
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A.C. PHILLIPS
R. J. BARLOW and A. R. BARNETT
J. LILLEY

The Physics of Stars, Second Edition provides a concise, self-contained account of how key aspects of stellar structure, evolution and nucleosynthesis can be understood in terms of fundamental physics. Beginning with an introduction to astrophysical concepts using elementary physics, the book progresses to consider stellar properties in terms of more advanced physical ideas all of which are carefully explained before they are applied. The result is a balanced presentation of both fundamental physics and astrophysics. A major strength of the book is that the author does not evade challenging concepts, but carefully explains them, enabling the reader to gain a fuller understanding of the theory.

Carefully revised, this second edition now includes a chapter on Helioseismology.



Review of the Second Edition

"This book is...a superb textbook in terms of choice of content, its organisation and style of presentation. Phillips is one of the best of the currently available texts - its coverage, level, style and price are all in its favour."

*Dr M. Wilson,
Royal Holloway College, University of London*

Review of the First Edition

"The title tells it all: This is a compact and well-organised book... and it achieves wonderful success in presenting the physics of approximation, intuition and understanding. Its strengths are many."

Physics Today

"Phillips never lets the student out of his sight. And this student is encouraged, step-by-step, to reach a greater understanding of the subject. Every paragraph seems to be honed on tutorial experience, every equation is explained with great care, superfluous material is omitted and concepts are worked out from first principles. This is a university textbook *par excellence*, a classic that will be used for decades to come."

New Scientist

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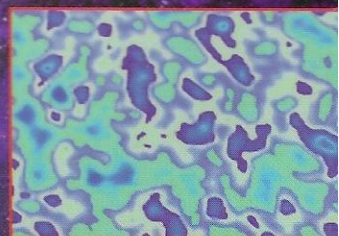


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Edited by **Mark H. Jones** and **Robert J. A. Lambourne**

An Introduction to

Galaxies and Cosmology



An Introduction to **Galaxies and Cosmology**

David J. Adams formerly University of Leicester, UK

Alan Cayless The Open University, Milton Keynes, UK

Anthony W. Jones The Open University, Milton Keynes, UK

Barrie W. Jones The Open University, Milton Keynes, UK

Mark H. Jones The Open University, Milton Keynes, UK

Robert J. A. Lambourne The Open University, Milton Keynes, UK

Lesley I. Onuora University of Sussex, UK

Sean G. Ryan The Open University, Milton Keynes, UK

Elizabeth Swinbank University of York, UK

Andrew N. Taylor University of Edinburgh, UK

For centuries astronomers and cosmologists have attempted to answer some of the most fundamental questions about the nature of our Universe. This introductory textbook presents our current understanding of the role of galaxies as 'building blocks' in the Universe and explains why the distances between galaxies are increasing as time progresses.

Starting with a detailed discussion of the structure and history of our own Galaxy, the Milky Way, this textbook goes on to give a general introduction to normal and active galaxies with a description of their physical properties and their distribution in space. It includes a review of the methods astronomers are currently using to tackle questions about the formation and evolution of galaxies. The second part of the book provides an introduction to a wide range of cosmological models and emphasizes the interplay between theory and observation in determining the nature of the cosmos. Models of the big bang and the expansion of the Universe are discussed and the book concludes by highlighting outstanding problems in modern cosmology.

Compiled by a team of experts, this textbook has been designed for elementary university courses in astronomy and cosmology, and is written in an accessible style that avoids complex mathematics. It is therefore suitable for self-study and will appeal to amateur astronomers as well as undergraduate students. The book includes many helpful features:

- numerous full-colour diagrams and photographs
- boxed summaries highlighting particular concepts and techniques
- bulleted questions and answers throughout the text
- over 100 student exercises with full solutions
- a glossary of terms
- a supporting website <http://publishing.cambridge.org/resources/0521546230> hosting sample pages, selected illustrations, further exercises and solutions and links to other related Internet resources.

Advance praise for this textbook:

'An Introduction to Galaxies and Cosmology is an impressive textbook. I found the presentation to be accessible to a wide variety of students, yet comprehensive and very up-to-date. The relevant mathematics and physics are introduced clearly and gently; advanced topics are explained in a pedagogically effective manner. The style of presentation will attract and sustain the interest of a broad spectrum of readers; it involves them in the drama of search, discovery, and emergence of new mysteries.'

Professor Robert Wagoner Stanford University, USA

'The authors have achieved a great deal by producing a comprehensive, and comprehensible textbook with very little mathematics. The chapters on cosmology are bang up-to-date, and succeed in putting across challenging concepts in an understandable way. The book is also well-illustrated and very nicely produced.'

Professor Alan Heavens University of Edinburgh, UK

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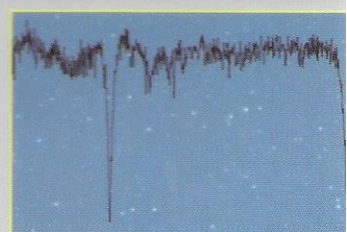
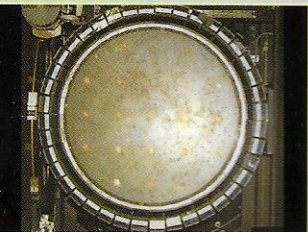
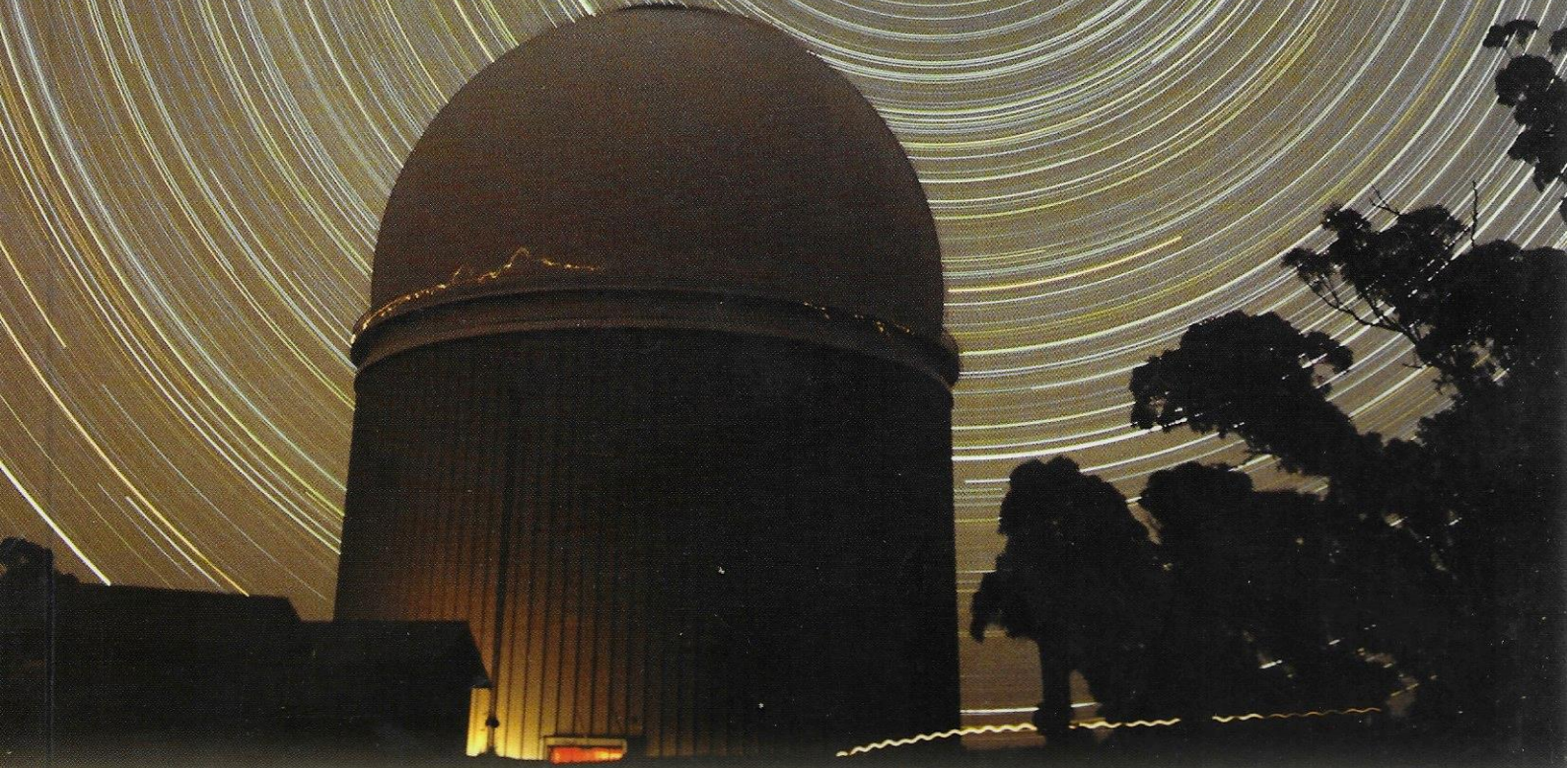
ISBN 0-521-54623-0



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Edited by **Andrew J. Norton**

Observing the Universe



Observing the Universe

A Guide to Observational Astronomy and Planetary Science

W. Alan Cooper *The Open University, Milton Keynes, UK*

Ian A. Franchi *The Open University, Milton Keynes, UK*

Stuart M. Freake *The Open University, Milton Keynes, UK*

Simon F. Green *The Open University, Milton Keynes, UK*

Carole A. Haswell *The Open University, Milton Keynes, UK*

Barrie W. Jones *The Open University, Milton Keynes, UK*

Ulrich C. Kolb *The Open University, Milton Keynes, UK*

T. J. Lowry McComb *Durham University, UK*

Andrew J. Norton *The Open University, Milton Keynes, UK*

David A. Rothery *The Open University, Milton Keynes, UK*

Sean G. Ryan *The Open University, Milton Keynes, UK*

The wonders of the Universe can be seen by anyone who gazes into the sky on a clear night. The powerful tools and techniques of modern astronomy and planetary science go well beyond this and unravel the mysteries of the Universe in unprecedented detail.

This book provides a sound basis for tackling astronomy and planetary science observations in the first couple of years of a university course. It concentrates on generic aspects of these observations: the principles of telescopes and detectors, photometry and spectroscopy, microscopy techniques for analysing extraterrestrial samples, interpreting planetary images, teamwork skills, planning for a session at an observatory, keeping records of what you do, estimating uncertainties in measurements, analysing data numerically and graphically, and producing a written report.

Compiled by a team of experts, this textbook introduces a range of techniques and skills designed for students who are undertaking observational work in astronomy and planetary science. It is written in an accessible style that avoids complex mathematics. It is suitable for self-study and will appeal to amateur enthusiasts as well as undergraduate students. The book includes many helpful features:

- numerous full-colour diagrams and photographs
- boxed summaries highlighting particular concepts and techniques
- bulleted questions and answers throughout the text
- many self-assessment exercises with full solutions
- extensive cross-referenced glossary of terms.

'... a good basic introduction to modern techniques used in optical astronomy and planetary science. It will appeal not only to undergraduates on astronomy courses about to be let loose on a telescope for the first time, but also to amateur astronomers who wish to obtain scientific results from their observations.'

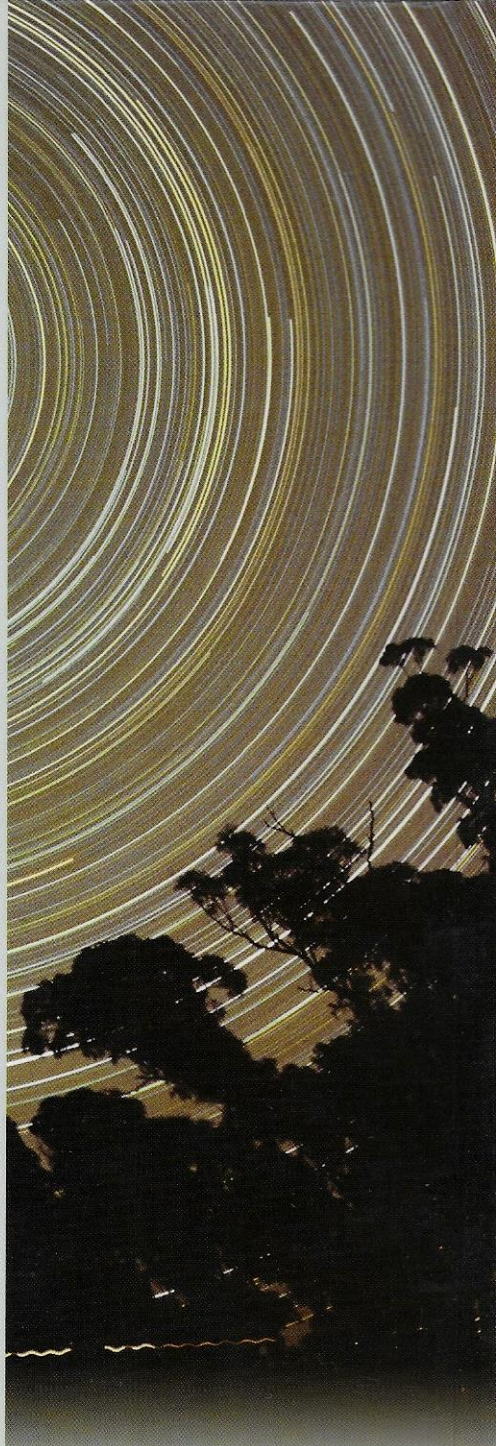
Dr. Paula Chadwick, Department of Physics, University of Durham

'Even [those] who don't want to treat data mathematically will welcome the practical and clear explanations. This book goes beyond the typical astronomy lab book ... Highly recommended.'

Dr. Mary Kay Hemenway, Astronomy Department, University of Texas at Austin

'Amidst the plethora of books on astronomy, this one's unique focus makes it particularly handy and appealing, and it can serve valuably as a springboard into the more complicated domain of the dedicated observer.'

Professor Charles M. Telesco, Astronomy Department, University of Florida



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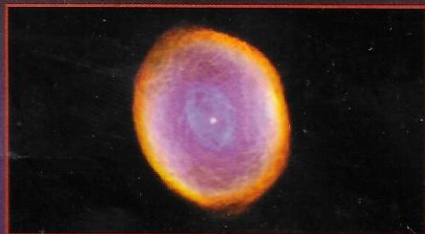
ISBN 0-521-60393-5



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Edited by **Simon F. Green** and **Mark H. Jones**

An Introduction to the **Sun and Stars**



An Introduction to the **Sun and Stars**

S. Jocelyn Bell Burnell *University of Bath, UK*

Simon F. Green *The Open University, Milton Keynes, UK*

Barrie W. Jones *The Open University, Milton Keynes, UK*

Mark H. Jones *The Open University, Milton Keynes, UK*

Robert J. A. Lambourne *The Open University, Milton Keynes, UK*

John C. Zarnecki *The Open University, Milton Keynes, UK*

With the Universe as a natural laboratory, astronomy has been the driving force for many of the greatest advances in science. This textbook is concerned with the properties and evolution of the objects most readily associated with astronomy – stars. What are the basic physical properties of stars? How bright are they? How massive are they? How are they distributed in space?

Starting with a detailed discussion of our nearest star, the Sun, this book describes how solar physicists have come to understand its internal workings. It then considers how astronomers go about studying the basic physical properties of more distant stars. This sets the scene for a description of the life-cycles of stars, starting from their formation in the interstellar medium, through their main sequence lifetimes, to the end points of stellar evolution. The book culminates with a discussion of the formation of exotic objects such as neutron stars and black holes.

Compiled by a team of experts, this textbook has been designed for elementary university courses in astronomy and astrophysics, and is written in an accessible style that avoids complex mathematics. It is therefore suitable for self-study and will appeal to amateur astronomers as well as undergraduate students. The book includes many helpful features:

- numerous full-colour diagrams and photographs
- boxed summaries highlighting particular concepts and techniques
- bulleted questions and answers throughout the text
- over 100 student exercises with full solutions
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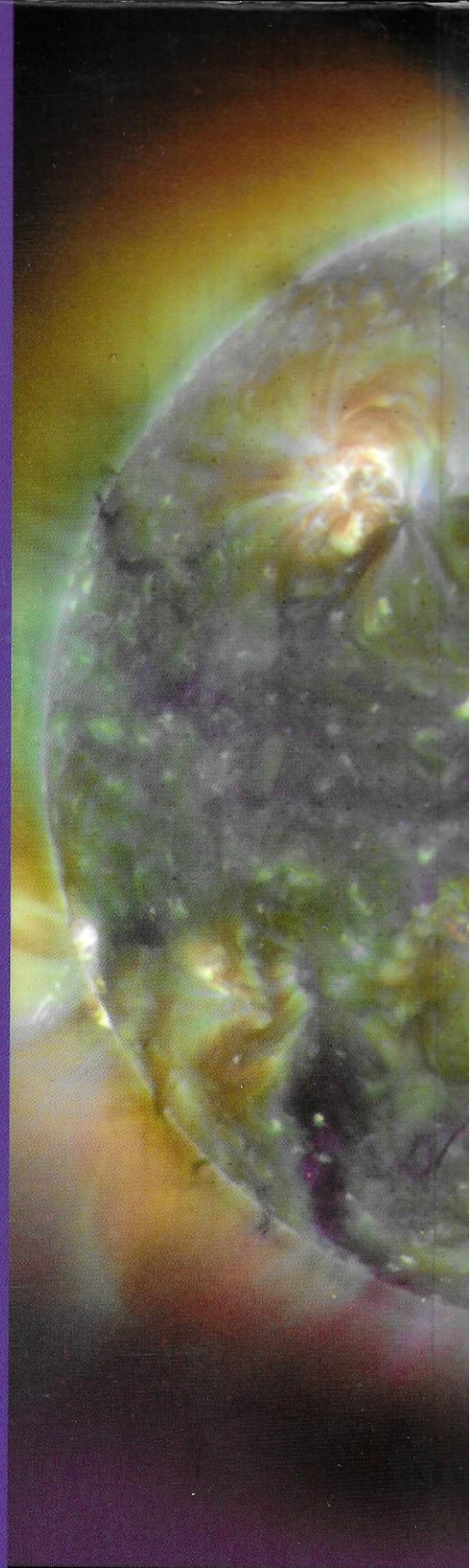
Advance praise for this textbook:

'This up-to-the-minute treatment of the universe of stars is the most enjoyable and informative book at this level that I have read. It combines clear physical arguments with excellent illustrations, and keen readers can enhance their depth of understanding through the copious worked examples. The 'biographies in boxes' also give a refreshing human perspective to the science. Good for coffee table or lecture course!'

Professor Peter Brand *University of Edinburgh, UK*

'*An Introduction to the Sun and Stars* is a real find for those of us who had previously despaired of finding a way to introduce the magic of "mere stars" to readers already aware of apparently more exotic phenomena in the universe. The illustrations are the best I have seen in this level of textbook and have clearly been carefully selected to bring alive the most exciting new discoveries. The accompanying text puts these discoveries into a solid context and explains the associated physics in simple but effective terms. This book will certainly appear on my recommended reading list for introductory astronomy.'

Professor Anneila Sargent *California Institute of Technology, USA*

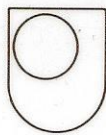


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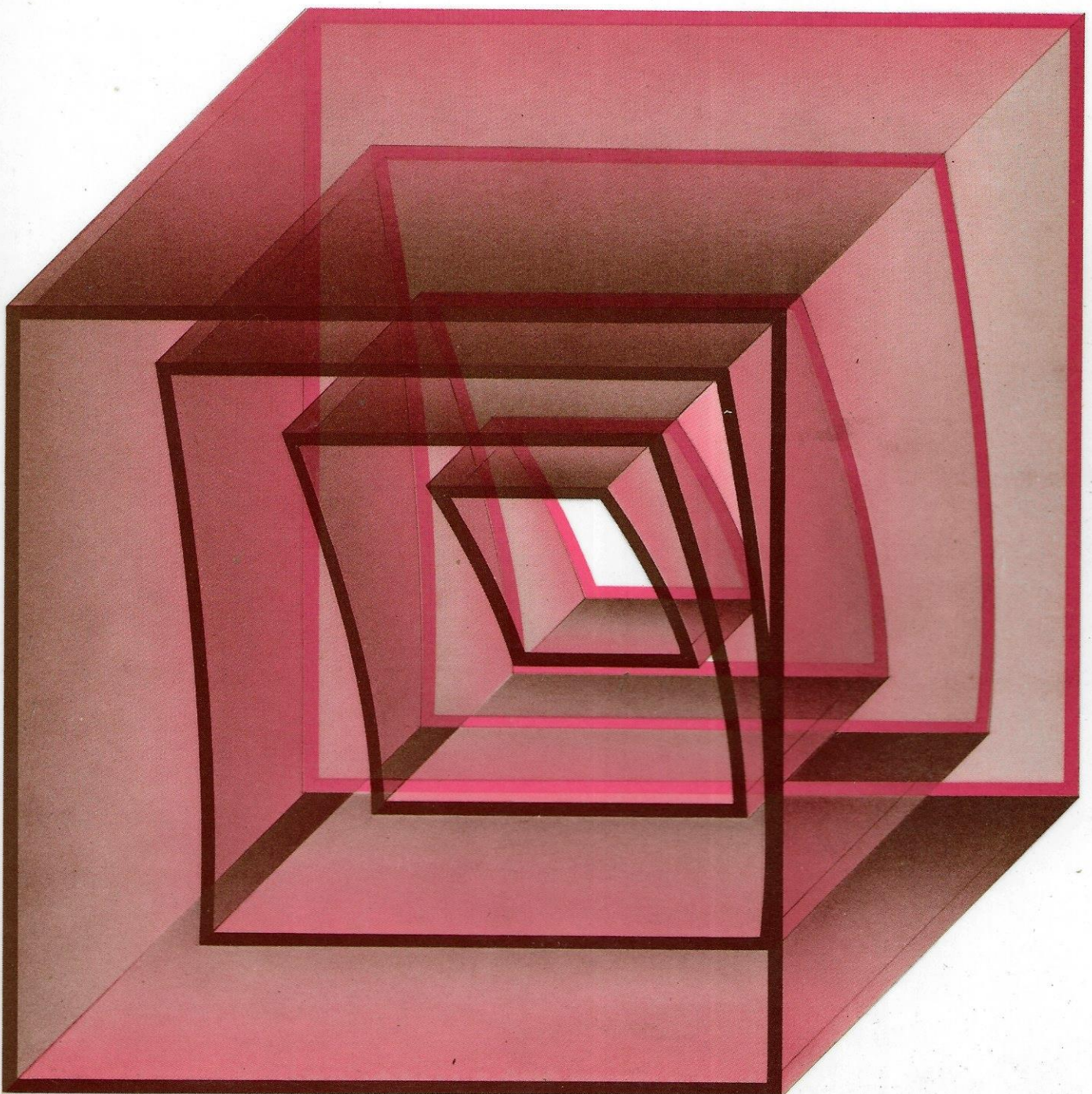


Science: A Third Level Course

UNDERSTANDING SPACE AND TIME

Block 1

Newtonian ideas in
Space and Time



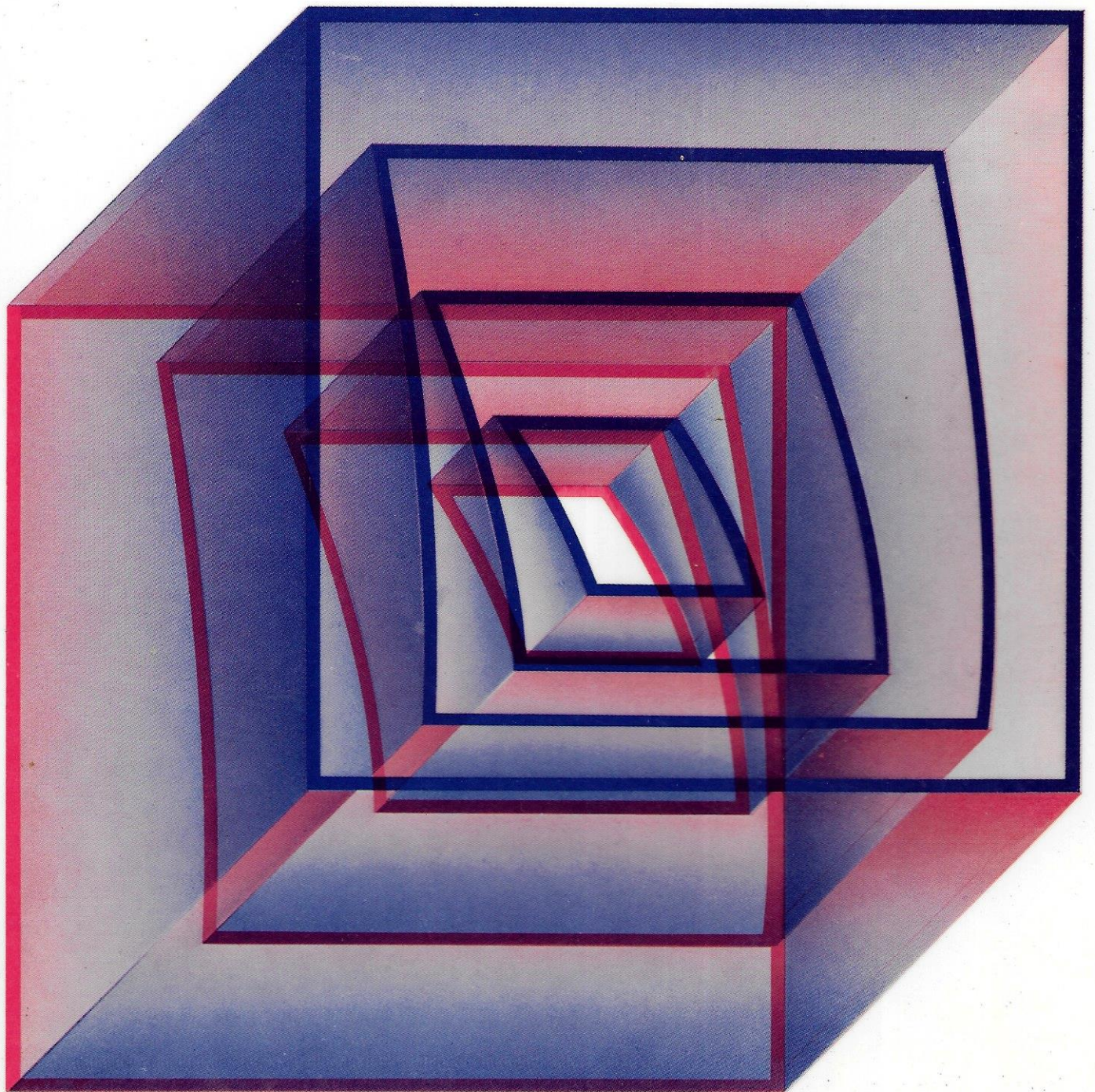


Science: A Third Level Course

UNDERSTANDING SPACE AND TIME

Block 2

Electromagnetism and Einstein's
special theory of relativity

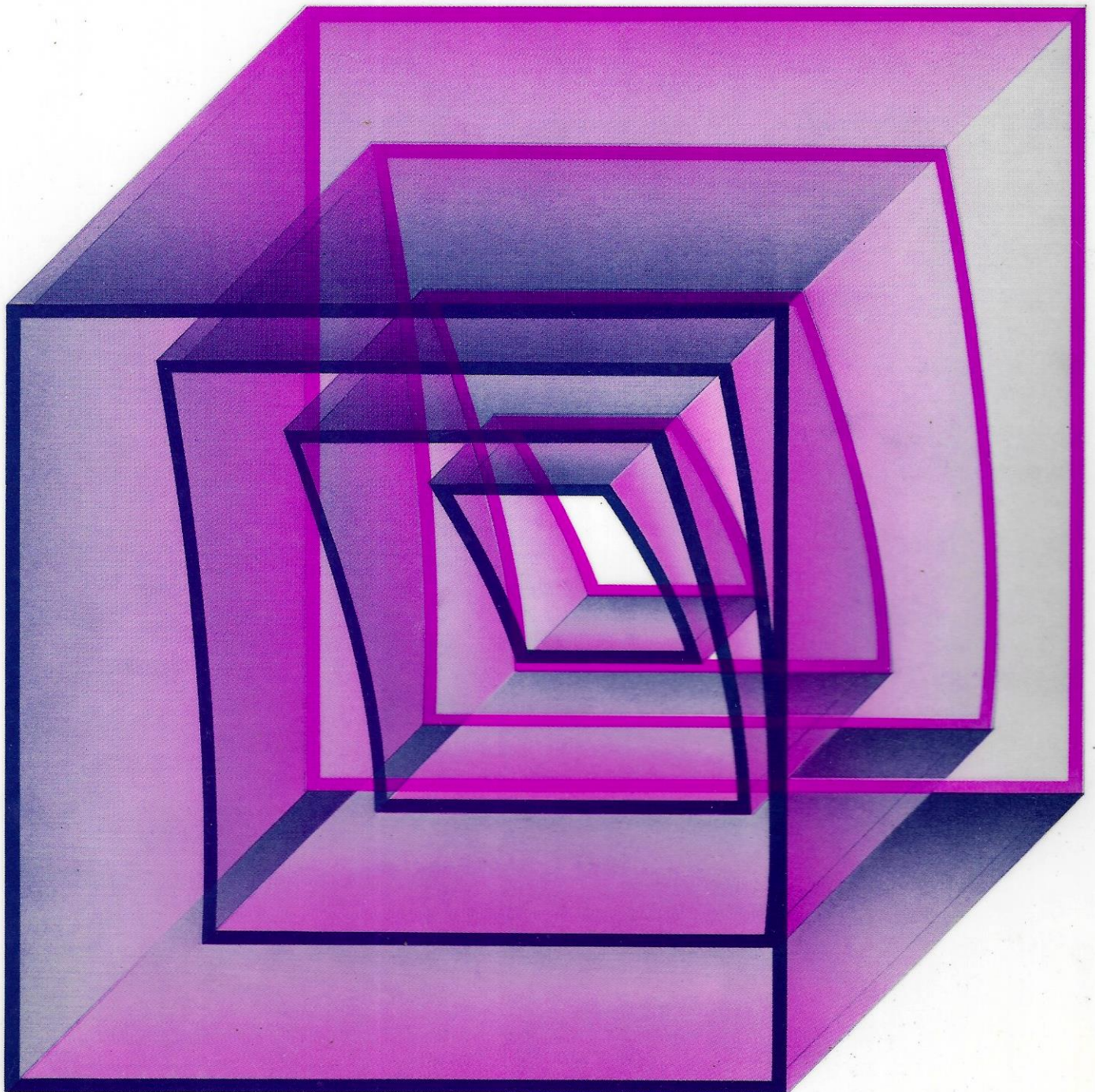


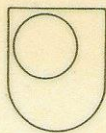


Science: A Third Level Course

UNDERSTANDING SPACE AND TIME

Block 3 Reflections

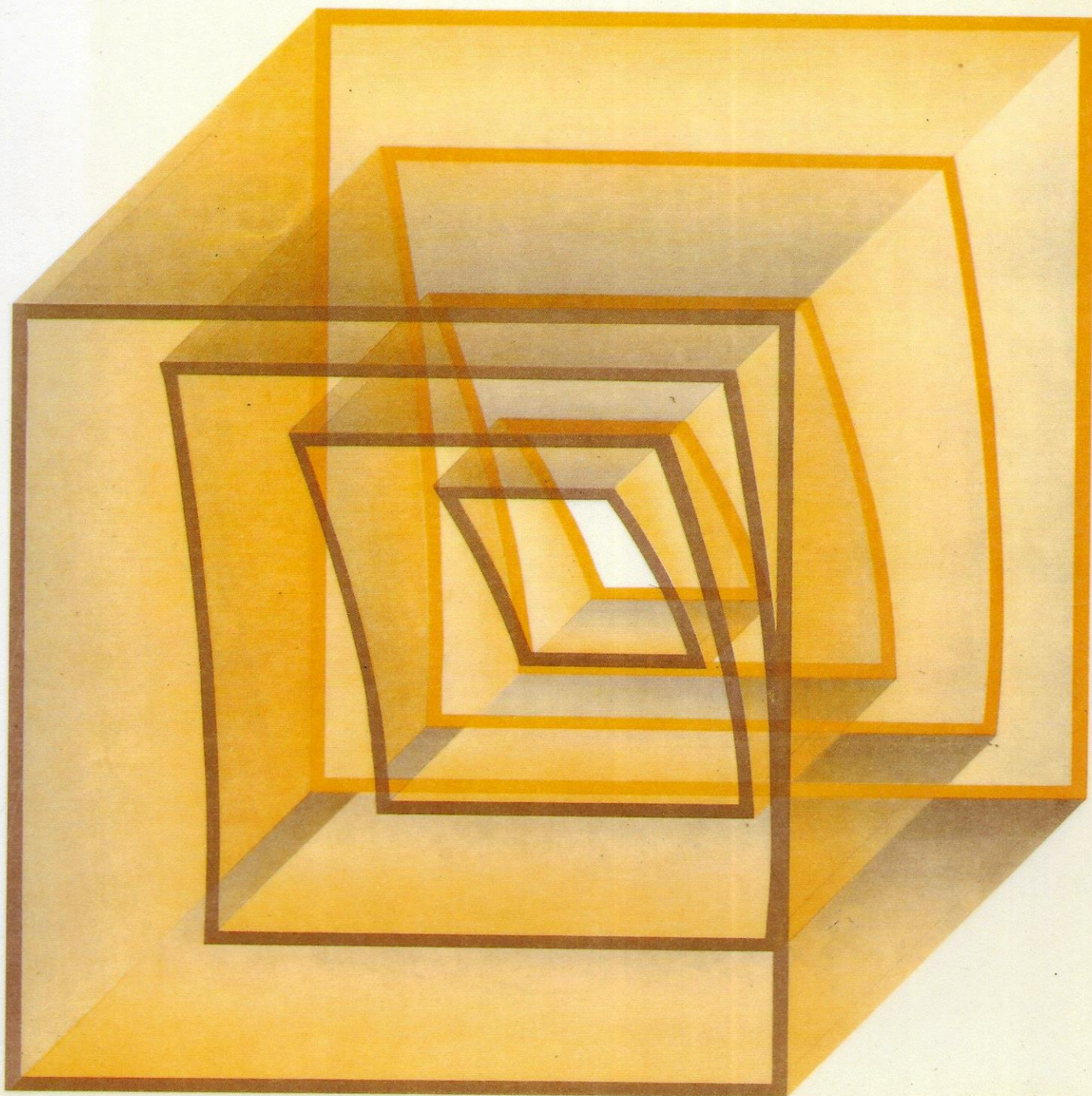




UNDERSTANDING SPACE AND TIME

Block 4

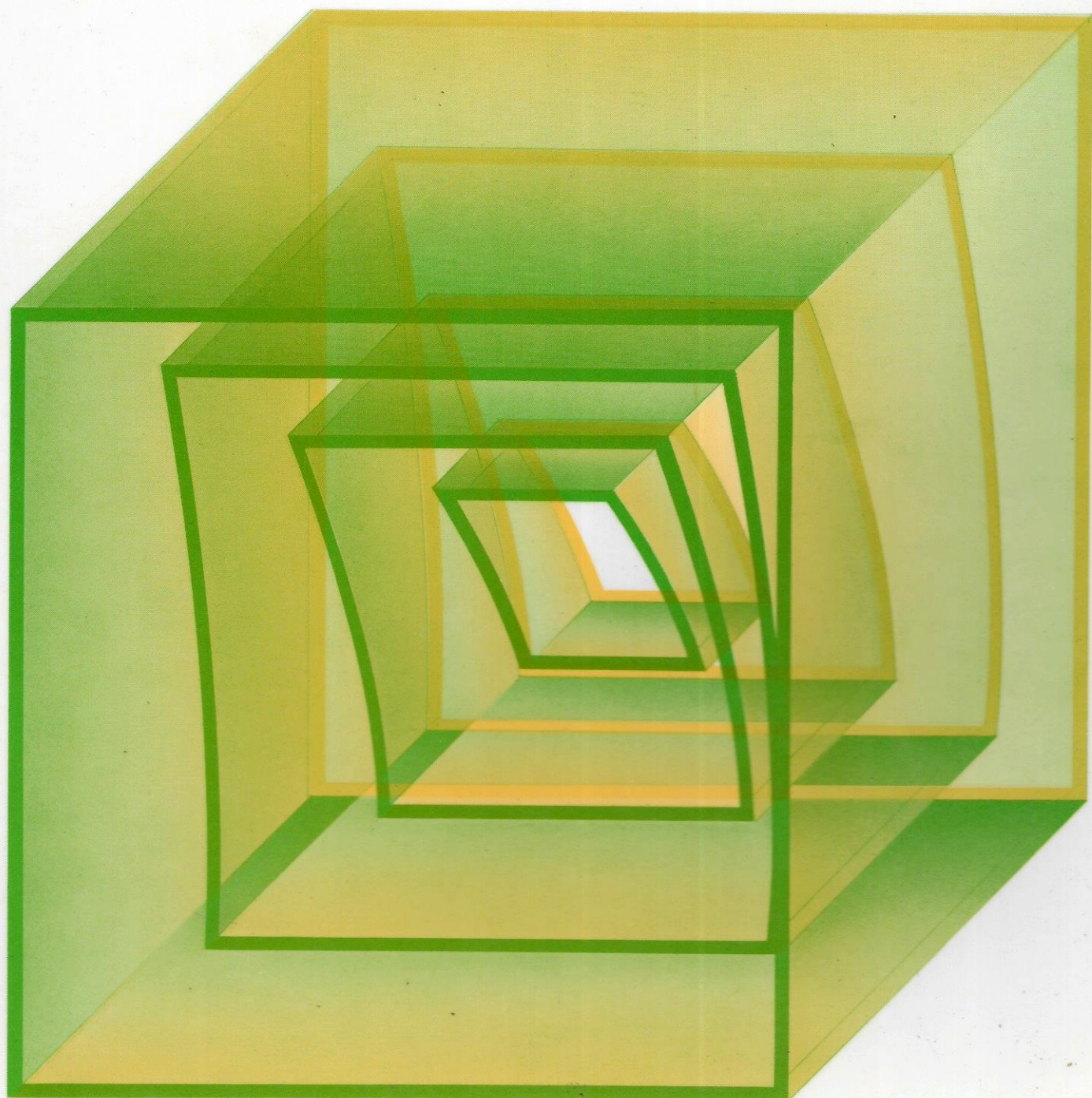
Gravitation and Einstein's
general theory of relativity





UNDERSTANDING SPACE AND TIME

Block 5 Cosmology

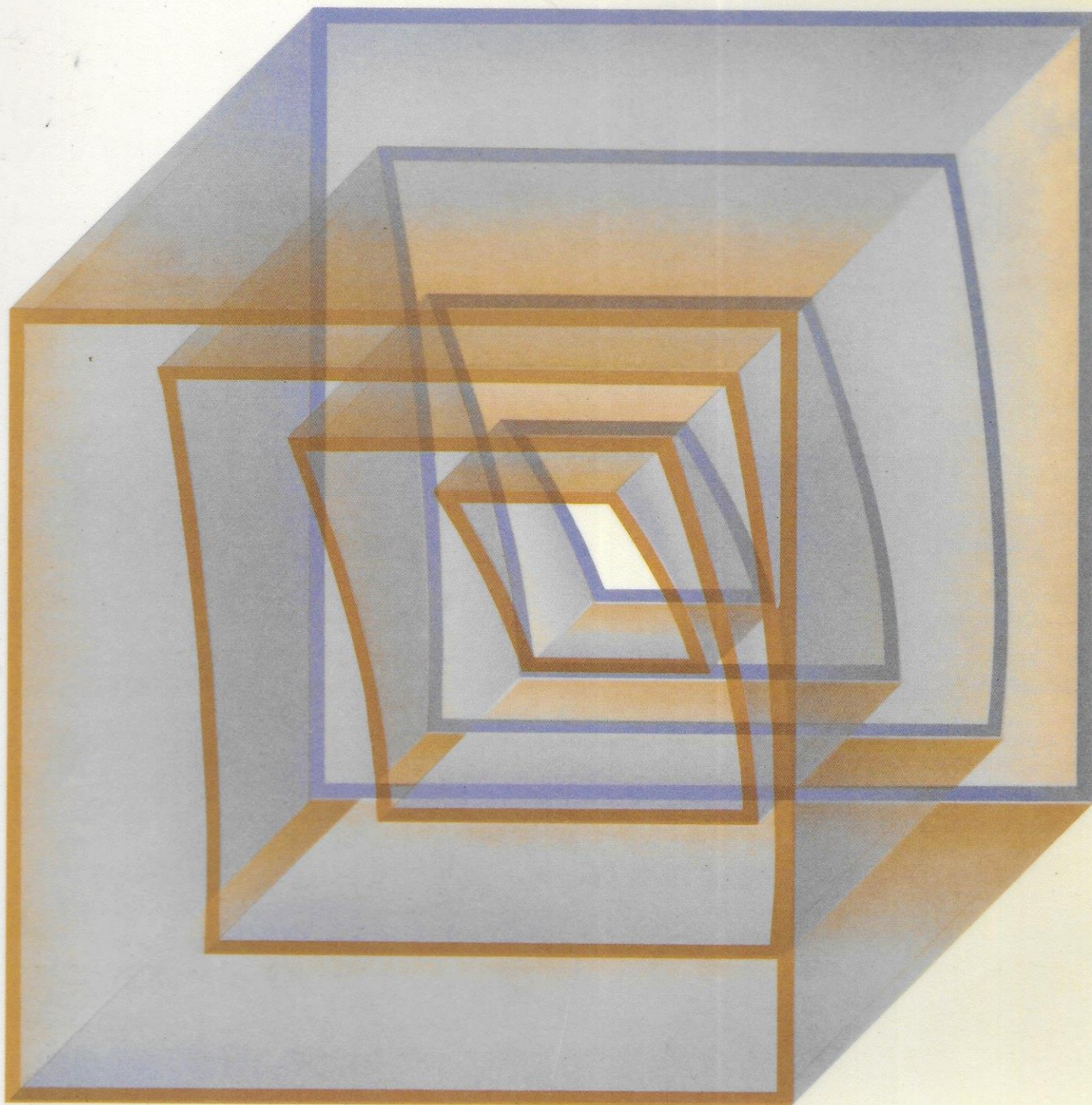




UNDERSTANDING SPACE AND TIME

Block 6

Topics in Space and Time



Space, Time and Cosmology



BLOCK 1

Newtonian ideas of space and time

Unit 1 Space and time – the setting for the motion of a particle

Unit 2 Newtonian mechanics

Unit 3 Symmetries and conservation laws

Space, Time and Cosmology



BLOCK 2

Electromagnetism and Einstein's special theory of relativity

Unit 4 Electromagnetic fields

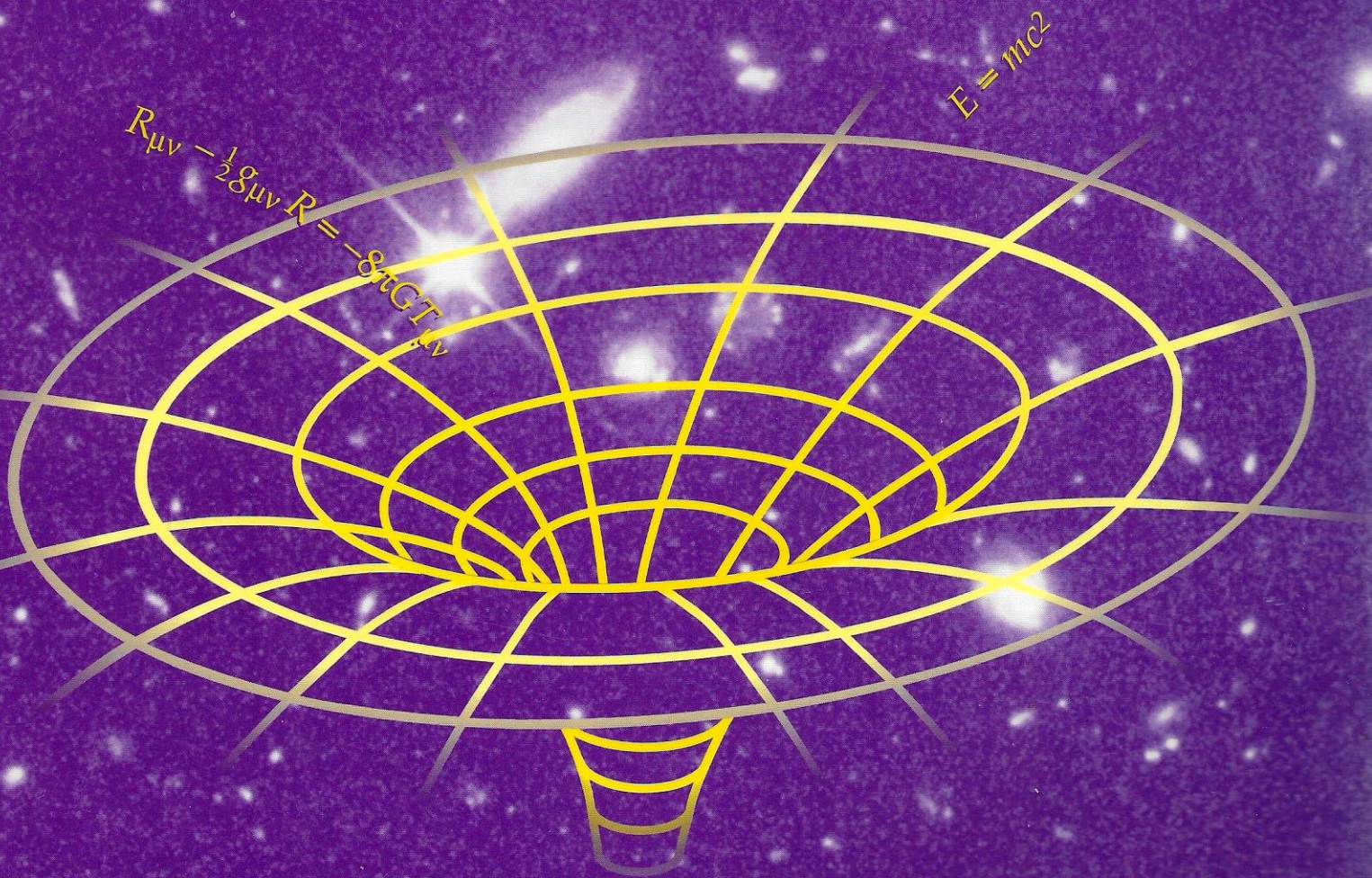
Unit 5 The need for special relativity

Unit 6 Some consequences of special relativity

Unit 7 Spacetime, momentum and energy

Unit 8 Consolidation and revision I

Space, Time and Cosmology



BLOCK 3

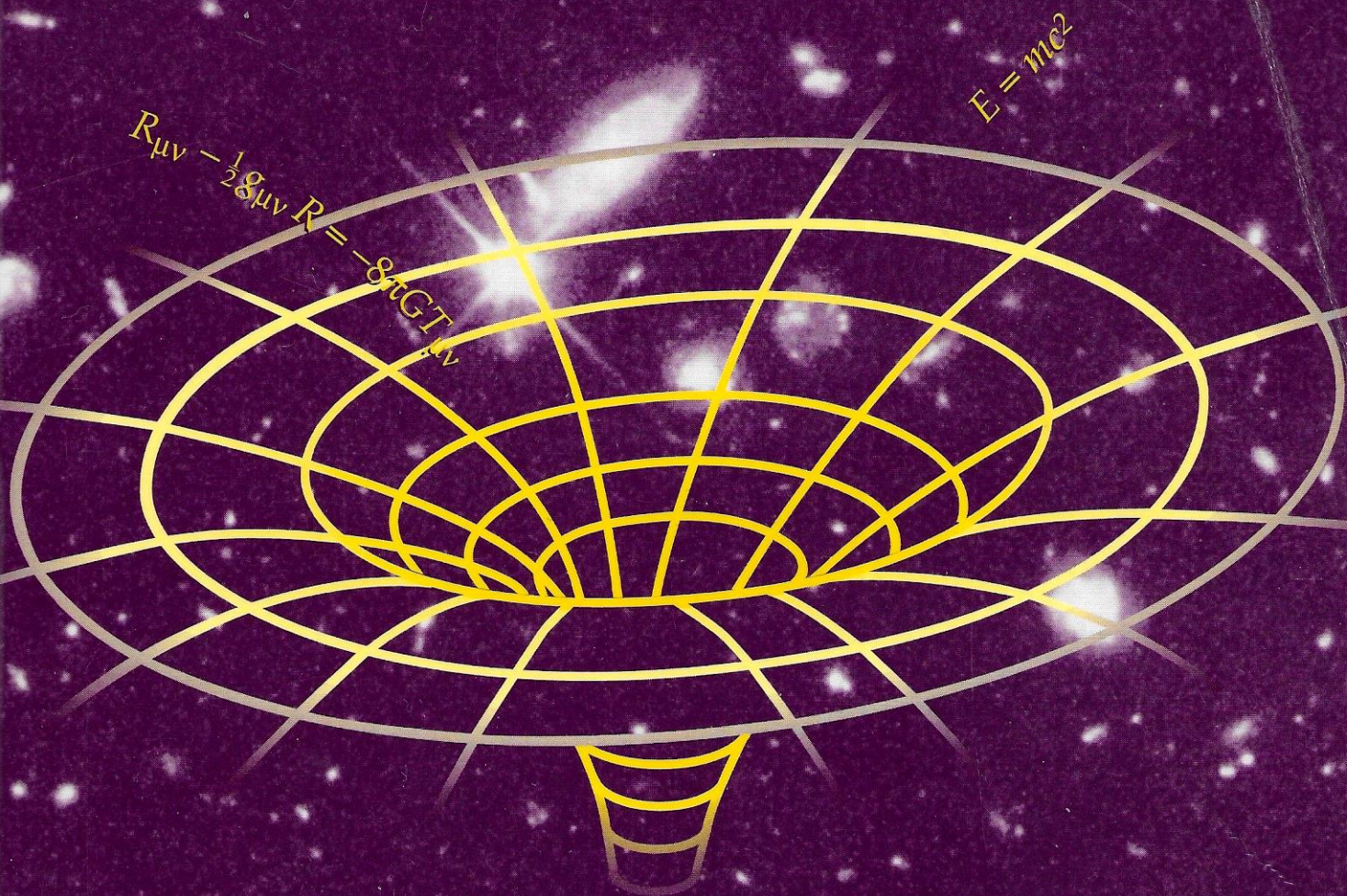
Gravitation, Einstein's general theory of relativity and black holes

Unit 9 First steps to a theory of gravitation

Unit 10&11 A metric theory of gravity and the field equations of general relativity

Unit 12 Black holes and other consequences of general relativity

Space, Time and Cosmology



BLOCK 4

Cosmology and the early Universe

Unit 13 The big bang

Unit 14 General relativity and cosmology

Unit 15 The evolution of the Universe

Unit 16 Consolidation and revision II

S381 Block 1
Science: Level 3



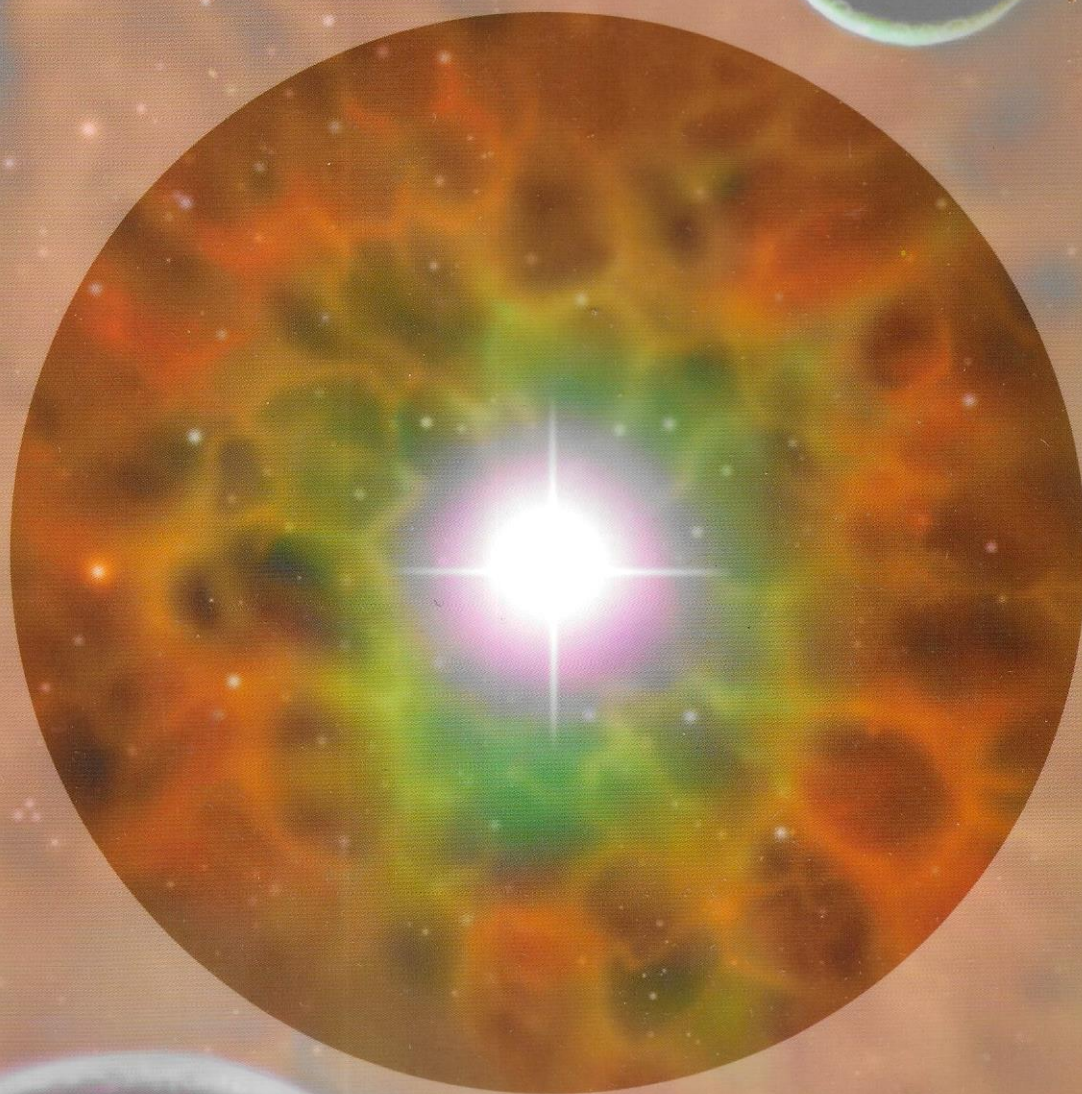
An Introduction to Astrophysics



S381
The
Energetic
Universe

Andrew Norton

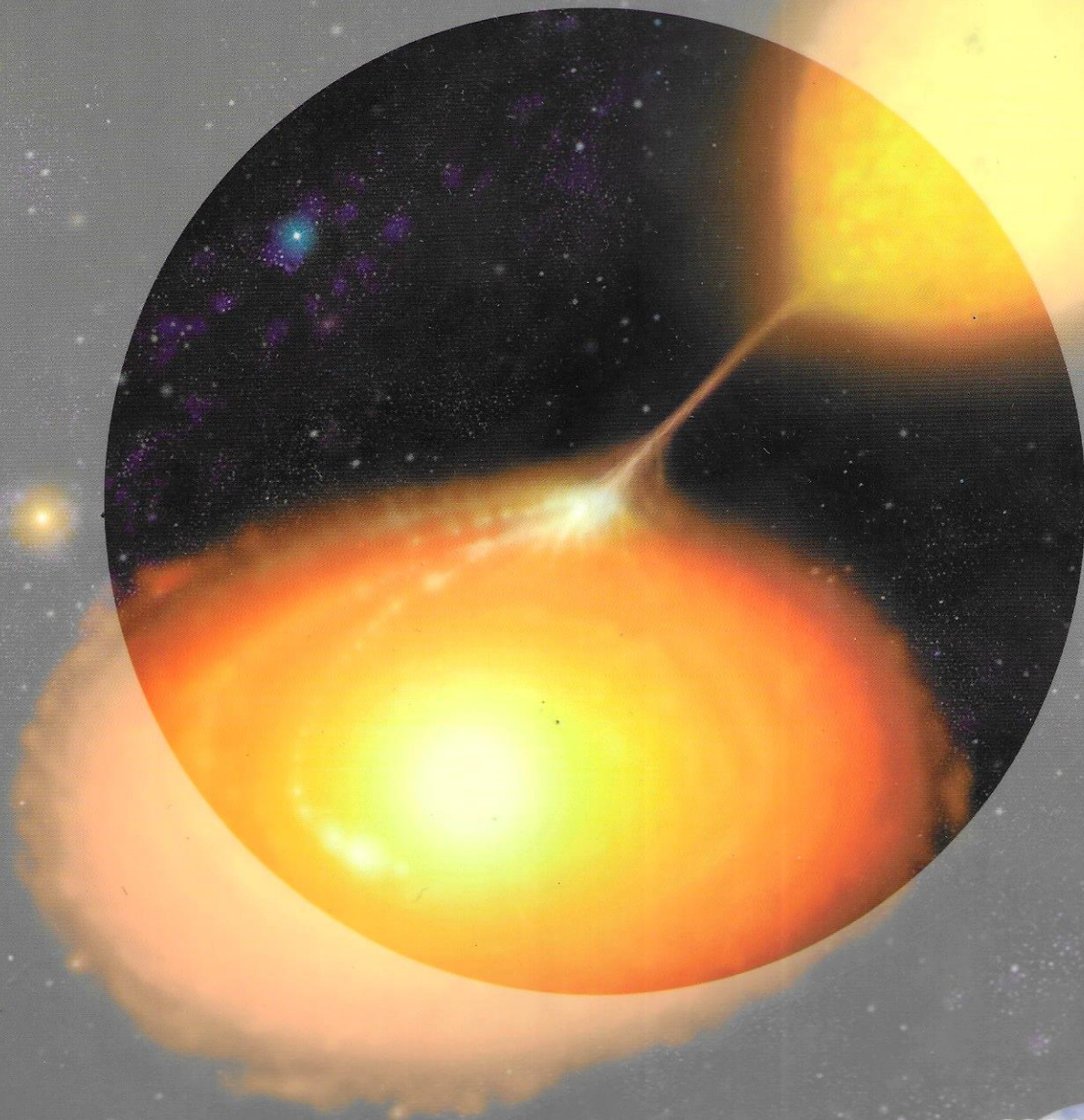
The Life and Death of Stars



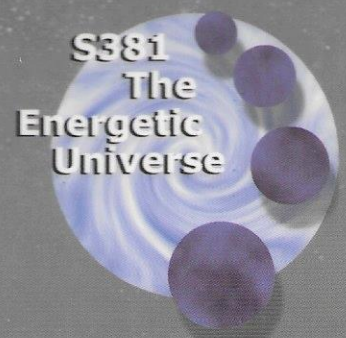
S381
The
Energetic
Universe

Sean Ryan

Interacting Binary Stars



Ulrich Kolb



The Energetic Universe

Block 1 An Introduction to Astrophysics

Block 2 The Life and Death of Stars

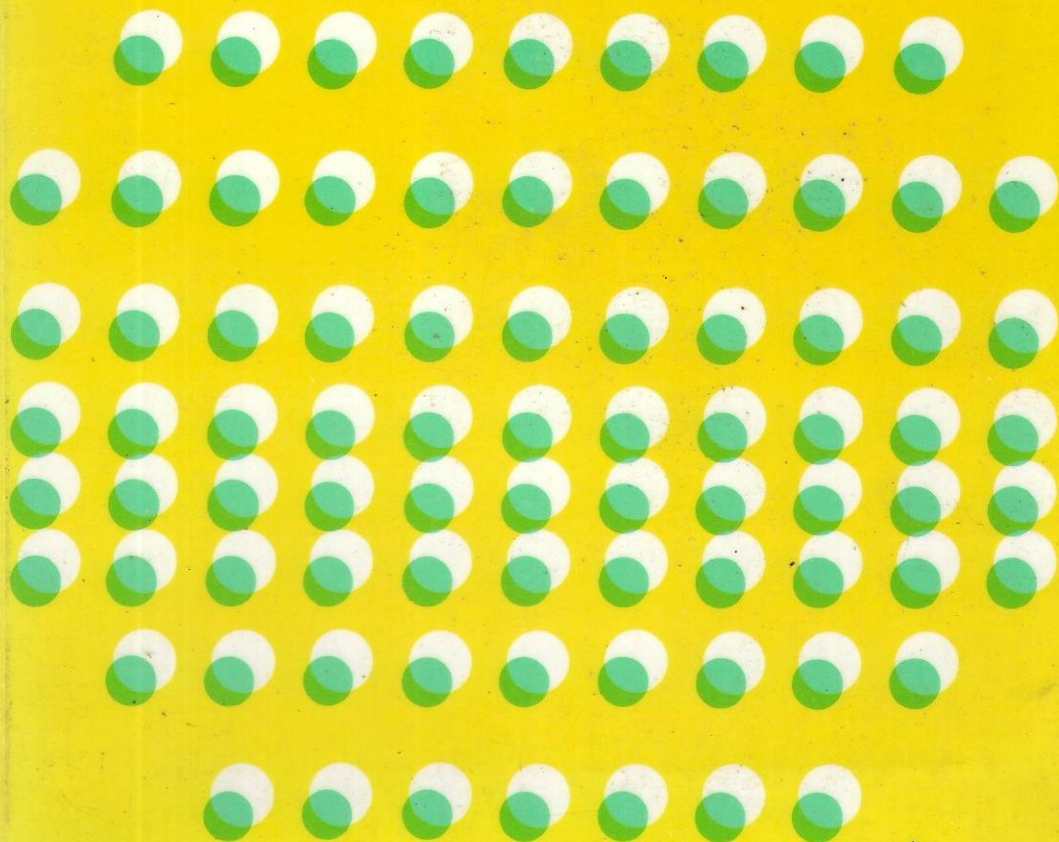
Block 3 Interacting Binary Stars

Block 4 Active Galaxies

An Introduction to Quantum Physics

A. P. French &
E. F. Taylor

M.I.T.
Introductory
physics
series



M.I.T. Introductory physics series

The M.I.T. Introductory Physics Series is the result of a programme of careful study, planning, and development that began in 1960. The Education Research Center at the Massachusetts Institute of Technology (formerly the Science Teaching Center) was established to study the process of instruction, aids thereto, and the learning process itself, with special reference to science teaching at the university level. Generous support from the National Science Foundation and from the Kettering, Shell, Victoria, W. T. Grant, and Bing Foundations provided the means for assembling and maintaining an experienced staff to co-operate with members of the Institute's Physics Department in the examination, improvement, and development of physics curriculum materials for students planning careers in the sciences.

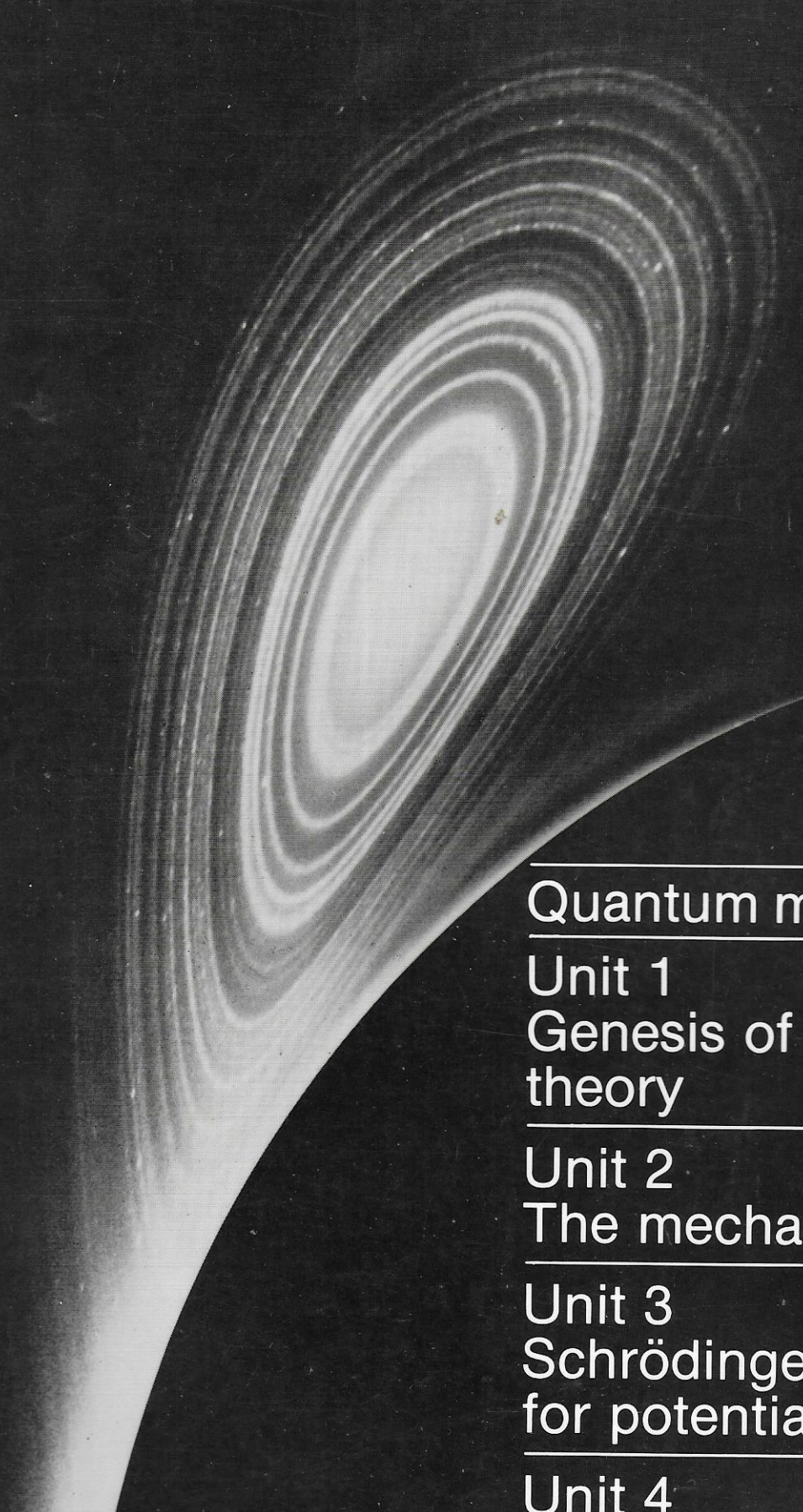
An Introduction to Quantum Physics

This book covers the fundamentals of quantum physics through the full Coulomb theory of the hydrogen atom, a semi-quantitative analysis of the helium atom, and a qualitative description of the build up of the periodic table, ending with a brief discussion of radiation by atoms. The emphasis throughout is on the experimental and theoretical underpinnings of quantum mechanics with examples from various areas of physics selected to illuminate how the theory works in practice. The authors have chosen to concentrate on a development of the Schrödinger method, but have introduced the matrix notation and indicated some relations between the two descriptions.

After careful analysis of objectives and the problems involved, preliminary versions of textbooks were prepared, tested through classroom use at M.I.T. and other institutions, re-evaluated, rewritten, and tried again. Only then were the final manuscripts undertaken. In general the books in the Series will be brief. Most may be covered in a single term or less. Each will be available in either cloth or paper binding. Their brevity and structure (as well as their reasonable price) will make it possible for teachers to select topics and organize courses according to individual needs and preferences. The complete series will cover the appropriate constituents for a wide variety of introductory one- and two-year courses at the university level.



The Open University
Science/Mathematics:
An interfaculty third level course
SM355 Quantum Mechanics



Quantum mechanics

Unit 1

Genesis of quantum theory

Unit 2

The mechanics of waves

Unit 3

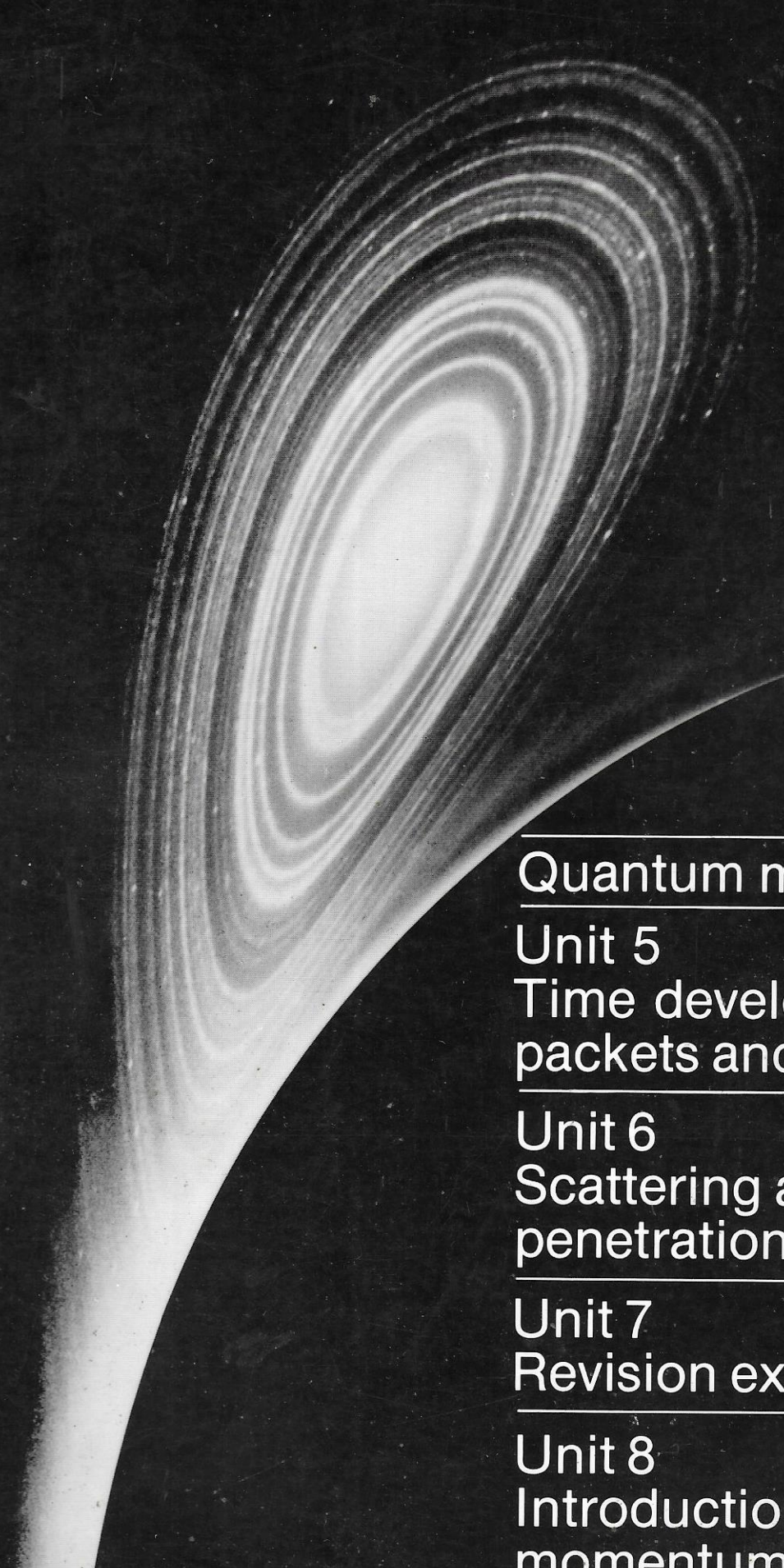
Schrödinger's equation for potential wells

Unit 4

The simple harmonic oscillator and the hydrogen atom



The Open University
Science/Mathematics:
An interfaculty third level course
SM355 Quantum Mechanics



Quantum mechanics

Unit 5

Time development, wave
packets and measurement

Unit 6

Scattering and barrier
penetration

Unit 7

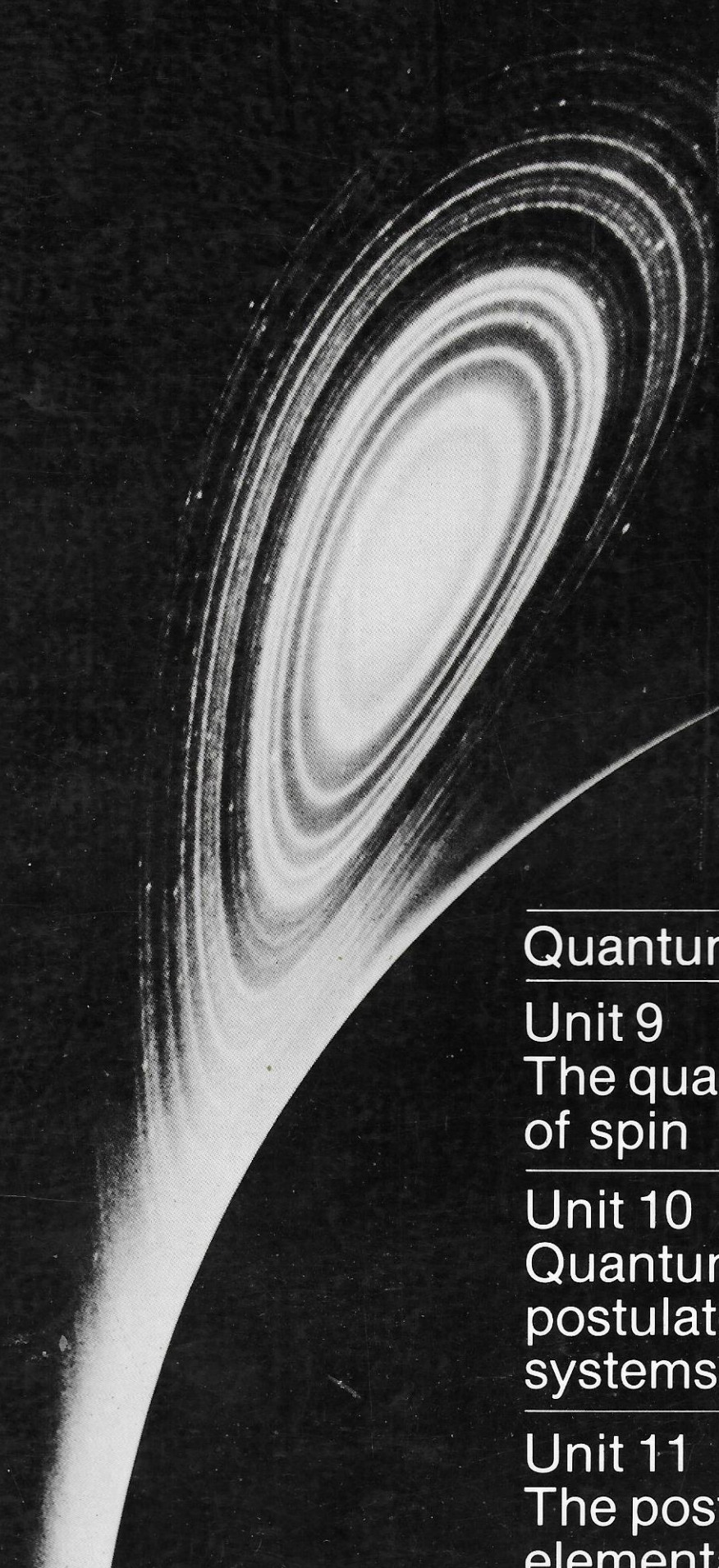
Revision exercises

Unit 8

Introduction to angular
momentum in quantum
mechanics



The Open University
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SM355 Quantum Mechanics



Quantum mechanics

Unit 9

The quantum theory of spin

Unit 10

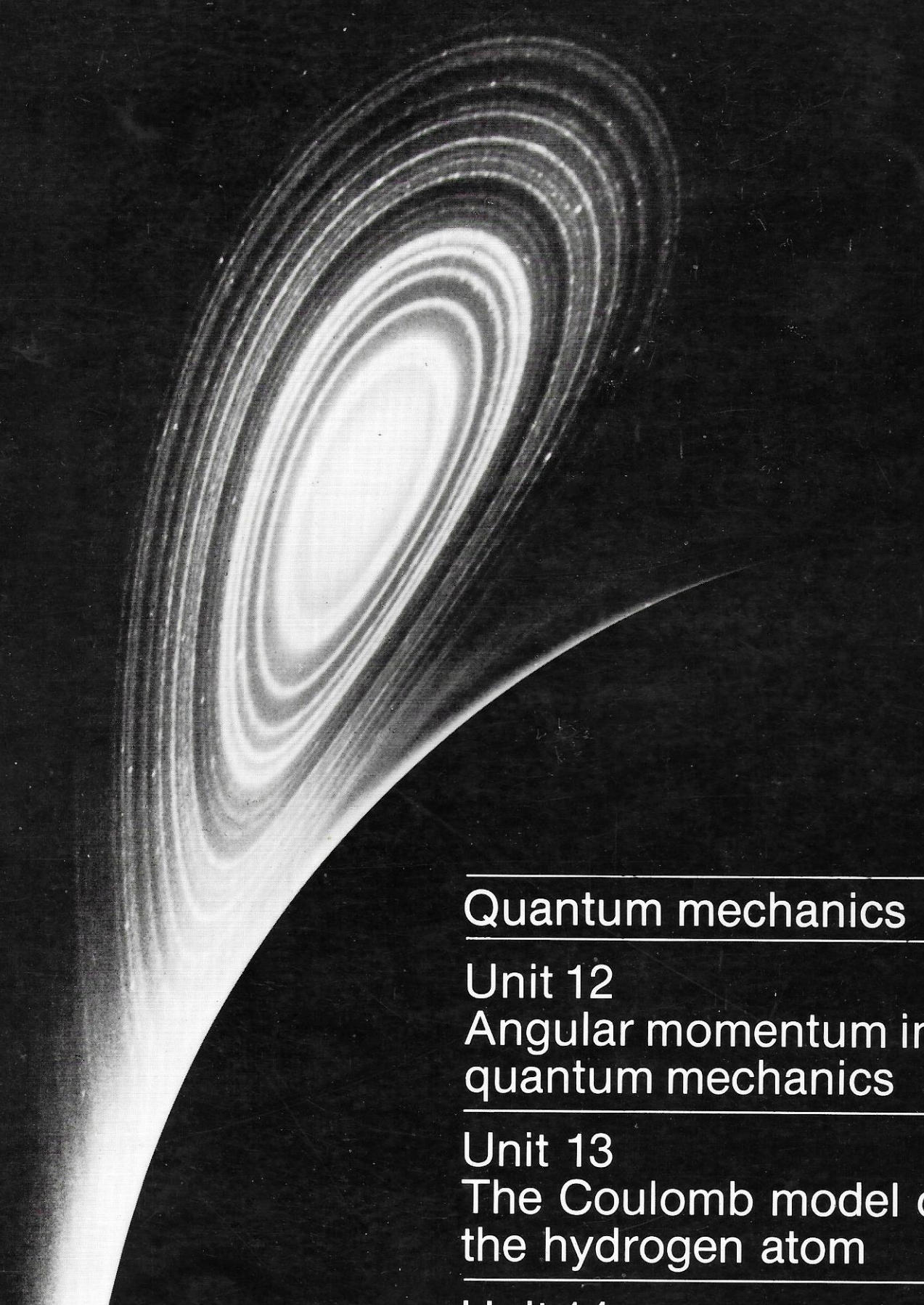
Quantum mechanical postulates for bound systems

Unit 11

The postulates of elementary quantum mechanics



The Open University
Science/Mathematics:
An interfaculty third level course
SM355 Quantum Mechanics



Quantum mechanics

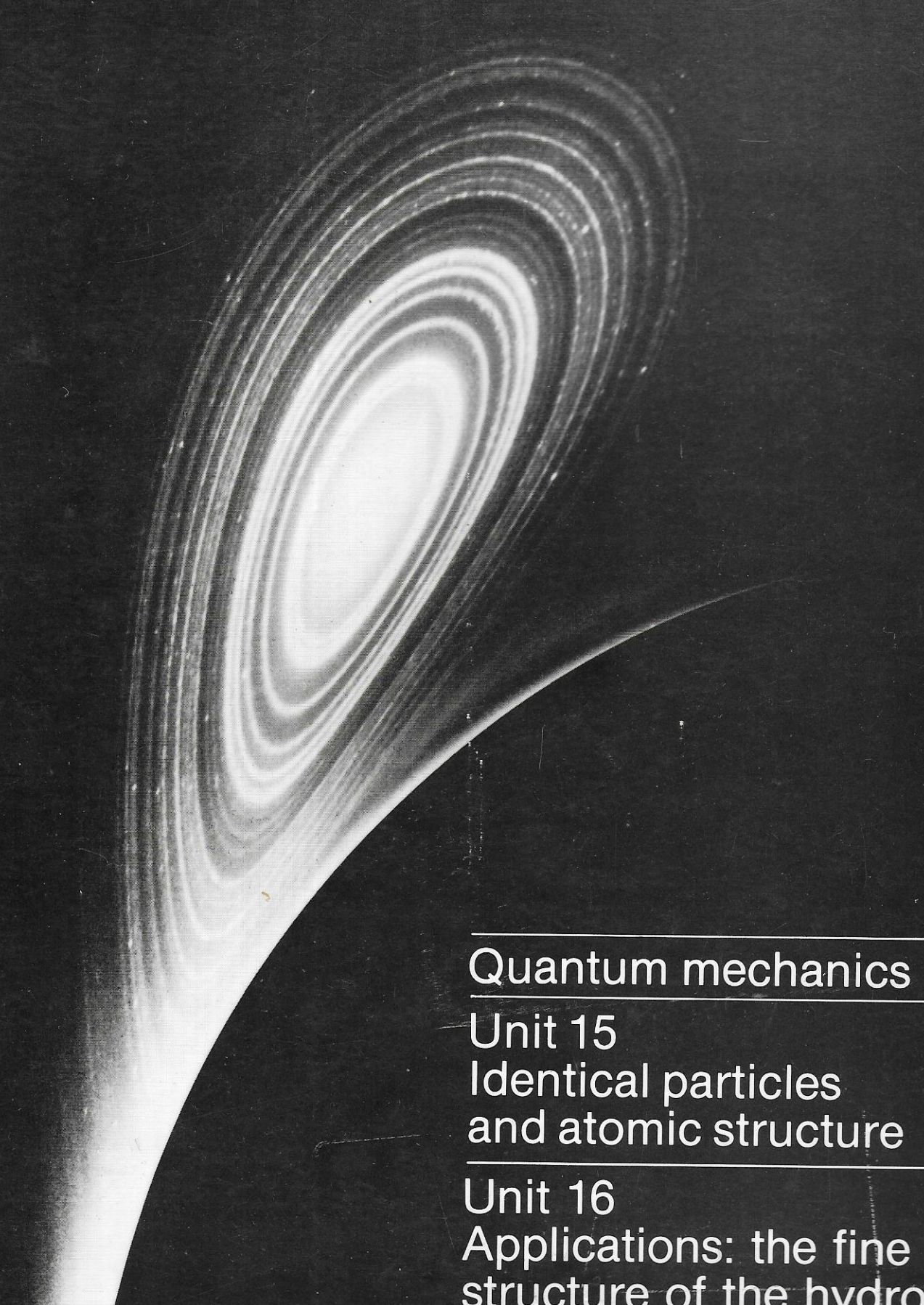
Unit 12
Angular momentum in
quantum mechanics

Unit 13
The Coulomb model of
the hydrogen atom

Unit 14
Approximation methods
in quantum mechanics



The Open University
Science/Mathematics:
An interfaculty third level course
SM355 Quantum Mechanics



Quantum mechanics

Unit 15

Identical particles
and atomic structure

Unit 16

Applications: the fine
structure of the hydrogen
atom, and the binding of
the hydrogen molecular
ion

Fundamental physical constants

<i>quantity</i>	<i>symbol</i>	<i>value</i>
Avogadro constant	N_A	$6.022 \times 10^{23} \text{ mol}^{-1}$
Bohr magneton	$\mu_B = \frac{e\hbar}{2m_e}$	$9.274 \times 10^{-24} \text{ J T}^{-1}$
Bohr radius	$a_0 = \frac{4\pi\epsilon_0\hbar^2}{m_e e^2}$	$5.292 \times 10^{-11} \text{ m}$
Compton wavelength of electron	$\lambda_0 = \frac{h}{m_e c}$	$2.426 \times 10^{-12} \text{ m}$
constant in Coulomb's law	$\frac{1}{4\pi\epsilon_0}$	$8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
electron charge/mass ratio	$-e/m_e$	$-1.759 \times 10^{11} \text{ C kg}^{-1}$
electron mass	m_e	$9.109 \times 10^{-31} \text{ kg}$
elementary charge	e	$1.602 \times 10^{-19} \text{ C}$
neutron mass	m_n	$1.675 \times 10^{-27} \text{ kg}$
Planck's constant	h	$6.626 \times 10^{-34} \text{ J s}$
	$\hbar = \frac{h}{2\pi}$	$1.055 \times 10^{-34} \text{ J s}$
proton mass	m_p	$1.673 \times 10^{-27} \text{ kg}$
Rydberg constant for hydrogen	$R_H = \left(\frac{1}{4\pi\epsilon_0}\right)^2 \frac{2\pi^2 m_e e^4}{h^3 c}$	$1.097 \times 10^7 \text{ m}^{-1}$
speed of light in vacuum	c	$2.998 \times 10^8 \text{ m s}^{-1}$

Useful conversions

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

$$1 \text{ erg} = 10^{-7} \text{ J}$$

$$1 \text{ gauss} = 10^{-4} \text{ T}$$

$$1 \text{ \AA} = 10^{-10} \text{ m}$$

SM358 The Quantum World
Science: Level 3
Book 1



The Open University

Wave mechanics



Book 1 Wave mechanics

Book 2 Quantum mechanics and its interpretation

Book 3 Quantum mechanics of matter

SM358 The Quantum World
Science: Level 3
Book 2



The Open University

Quantum mechanics and its interpretation



SM358 The Quantum World

Book 1 Wave mechanics

Book 2 Quantum mechanics and its interpretation

Book 3 Quantum mechanics of matter

ISBN 978 0 7492 1899 7

SM358 The Quantum World
Science: Level 3
Book 3



The Open University

Quantum mechanics of matter



SM358 The Quantum World

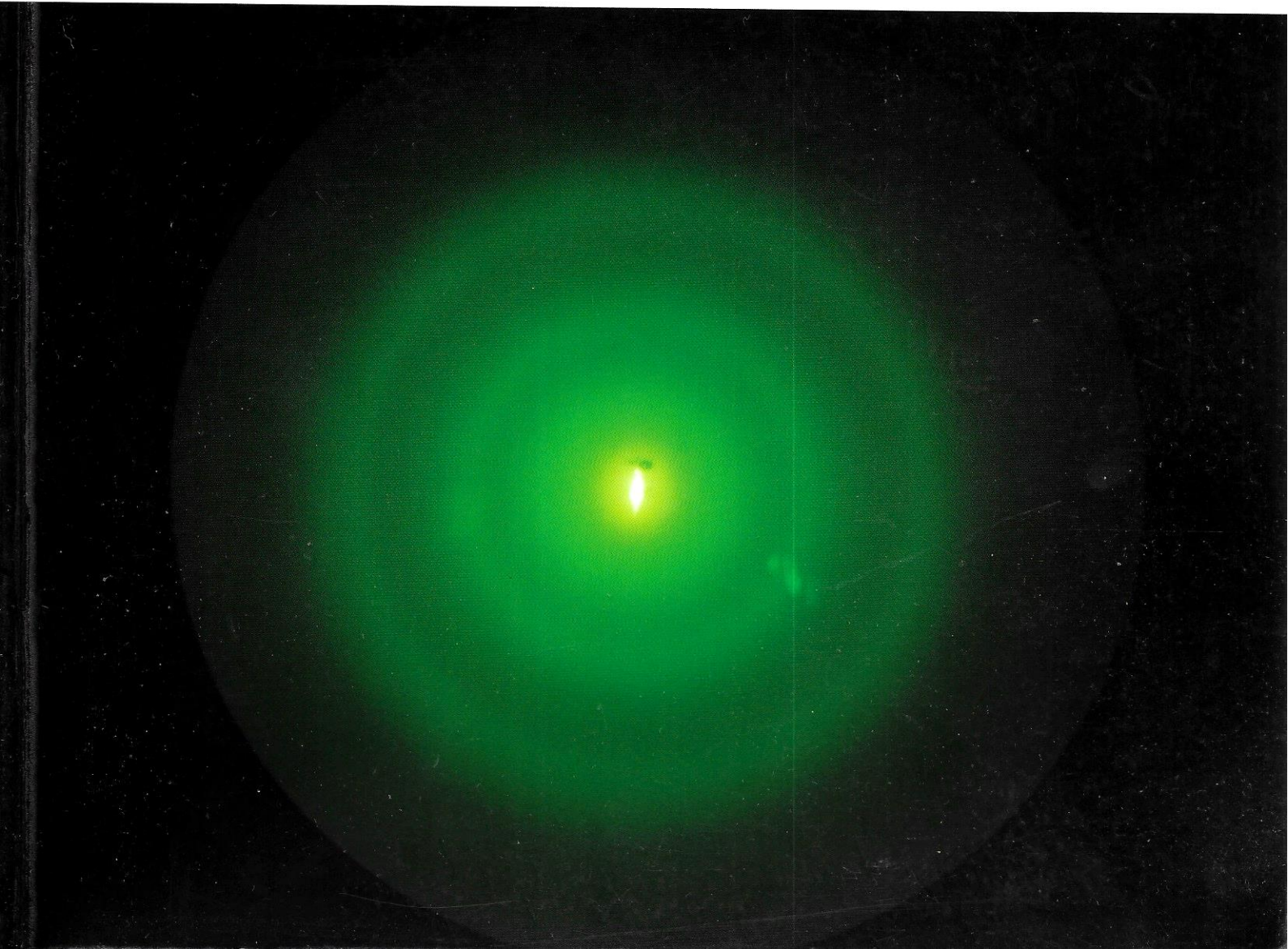
Book 1 Wave mechanics

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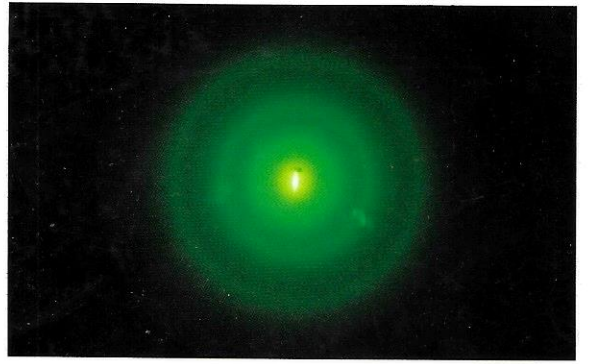


Quantum mechanics: experiments, applications and simulations



SMXR358

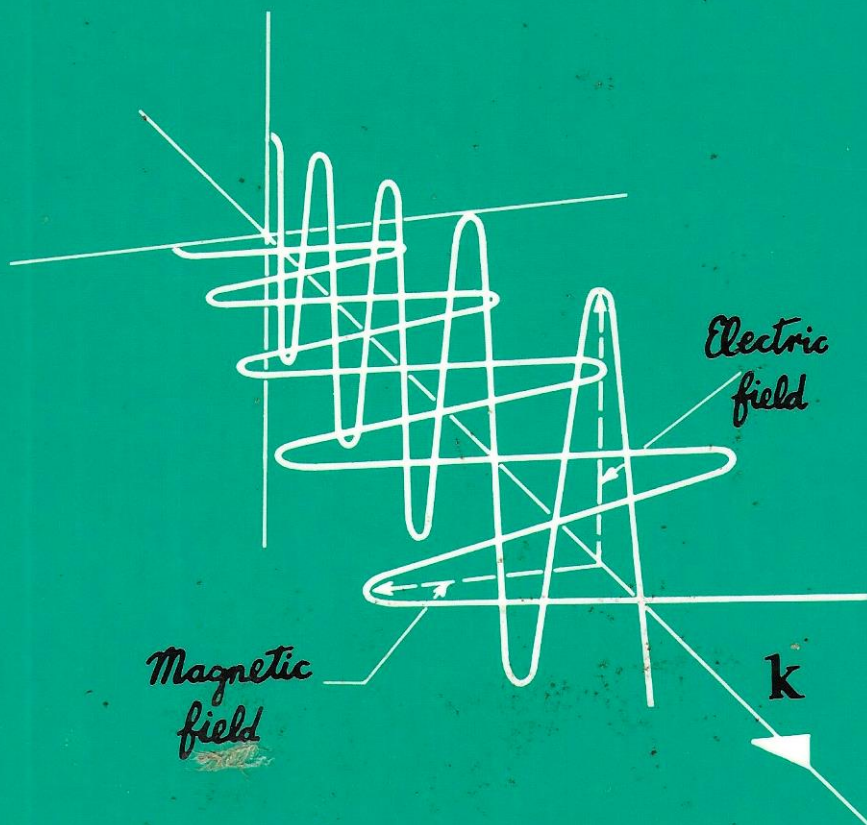
Quantum mechanics: experiments,
applications and simulations



Electromagnetism

I.S. GRANT · W.R. PHILLIPS

Second Edition



This book is intended as a general course on electromagnetism for physics students. The arrangement of the material allows considerable flexibility in its use for courses of different length and structure. For example, A.C. theory may come at the beginning, convenient for laboratory work, or it can follow the basic laws of electricity and magnetism. Calculus and an elementary knowledge of vectors are assumed. However, at their first appearance, the properties of the differential operators *div*, *grad* and *curl* are described in sufficient detail for what is needed in this book and to set them in the context of electromagnetism. A large collection of problems and hints for their solution is included.

For the second edition, the authors have updated and revised the original text, giving modern examples to illustrate how the laws of electromagnetism are applied to practical problems.

The book is a recommended text at numerous institutions, and has been adopted by the Open University as the course book for its new high-level course on electromagnetism.

The Manchester Physics Series is a collection of textbooks suitable for an undergraduate degree course in Physics. Each book has been individually developed to provide a reliable, self-contained text for an up-to-date course. Each book can be used independently of the other books in the series, while the organization and scope of each book allows considerable flexibility in the selection and arrangement of different courses.

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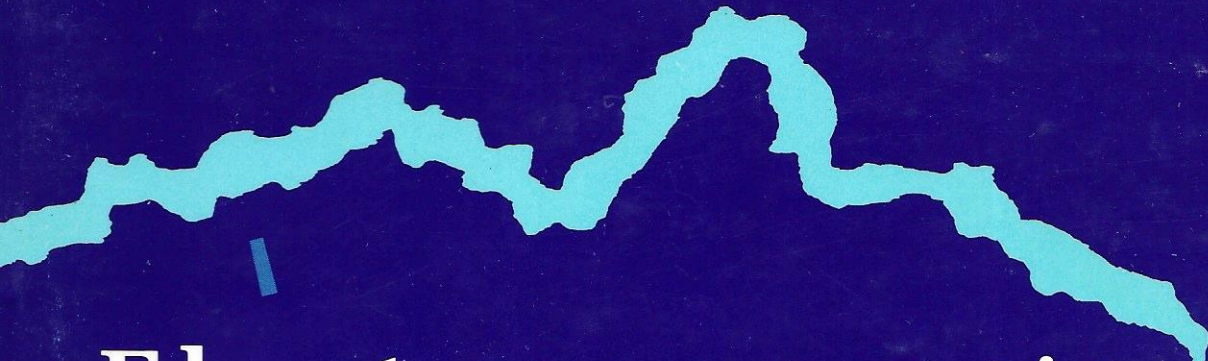
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Electromagnetism

Unit 1

Unit 1

Mathematical
preliminaries

Fundamental physical constants

Symbol	Quantity	Value
c	speed of light in vacuum	$2.998 \times 10^8 \text{ m s}^{-1}$
μ_0	permeability of free space	$4\pi \times 10^{-7} \text{ H m}^{-1}$ (or kg m C^{-2})
ϵ_0	permittivity of free space	$8.854 \times 10^{-12} \text{ F m}^{-1}$ (or $\text{C}^2 \text{ N}^{-1} \text{ m}^{-2}$)
$1/4\pi\epsilon_0$	(factor for Coulomb's law)	$8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
e	charge on proton	$1.602 \times 10^{-19} \text{ C}$
m_e	electron mass	$9.110 \times 10^{-31} \text{ kg}$
m_p	proton mass	$1.673 \times 10^{-27} \text{ kg}$
h	Planck's constant	$6.626 \times 10^{-34} \text{ J s}$
N_A	Avogadro's number	$6.022 \times 10^{23} \text{ mol}^{-1}$

Useful conversion factors

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1 litre (l)	10^{-3} m^3	1 kilowatt hour (kWh)	$3.600 \times 10^6 \text{ J}$
1 gauss (G)	10^{-4} T	1 degree (°)	$(\pi/180) \text{ rad}$

Some properties of vectors and vector fields

Cartesian unit vectors $\mathbf{e}_x, \mathbf{e}_y, \mathbf{e}_z$

$$\mathbf{e}_x \cdot \mathbf{e}_x = \mathbf{e}_y \cdot \mathbf{e}_y = \mathbf{e}_z \cdot \mathbf{e}_z = 1 \quad \mathbf{e}_x \cdot \mathbf{e}_y = \mathbf{e}_y \cdot \mathbf{e}_z = \mathbf{e}_z \cdot \mathbf{e}_x = 0$$

$$\mathbf{e}_x \times \mathbf{e}_y = \mathbf{e}_z \quad \mathbf{e}_y \times \mathbf{e}_z = \mathbf{e}_x \quad \mathbf{e}_z \times \mathbf{e}_x = \mathbf{e}_y$$

Products of vectors in cartesian coordinates

For vector $\mathbf{a} = a_x \mathbf{e}_x + a_y \mathbf{e}_y + a_z \mathbf{e}_z$ and vector $\mathbf{b} = b_x \mathbf{e}_x + b_y \mathbf{e}_y + b_z \mathbf{e}_z$,

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Gradient of scalar field ψ

$$\text{grad } \psi = \nabla \psi = \frac{\partial \psi}{\partial x} \mathbf{e}_x + \frac{\partial \psi}{\partial y} \mathbf{e}_y + \frac{\partial \psi}{\partial z} \mathbf{e}_z$$

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Conversion between spherical polar and cartesian coordinates

$$x = r \sin \theta \cos \phi \quad y = r \sin \theta \sin \phi \quad z = r \cos \theta$$

SMT356 Units

- | | |
|---|--|
| 1 Mathematical preliminaries | 9 Electromagnetic induction and magnetic energy |
| 2 Electrostatics 1:
Fields and forces | 10 Revision exercises |
| 3 Electrostatics 2:
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| 5 Electrostatic field calculations | 13 Electromagnetic waves 1:
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| 7 Magnetostatics | 15 Waveguides and resonant cavities |
| 8 Magnetic materials | 16 Generation of electromagnetic waves |



Electromagnetism

Units 2–5

Unit 2

Electrostatics 1:
Fields and forces

Unit 3

Electrostatics 2:
Potential and
potential energy

Unit 4

Dielectrics

Unit 5

Electrostatic field
calculations

Fundamental physical constants

Symbol	Quantity	Value
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Electromagnetism

Units 6–9

Unit 6

Magnetic fields
and forces

Unit 7

Magnetostatics

Unit 8

Magnetic
materials

Unit 9

Electromagnetic
induction and
magnetic energy

Fundamental physical constants

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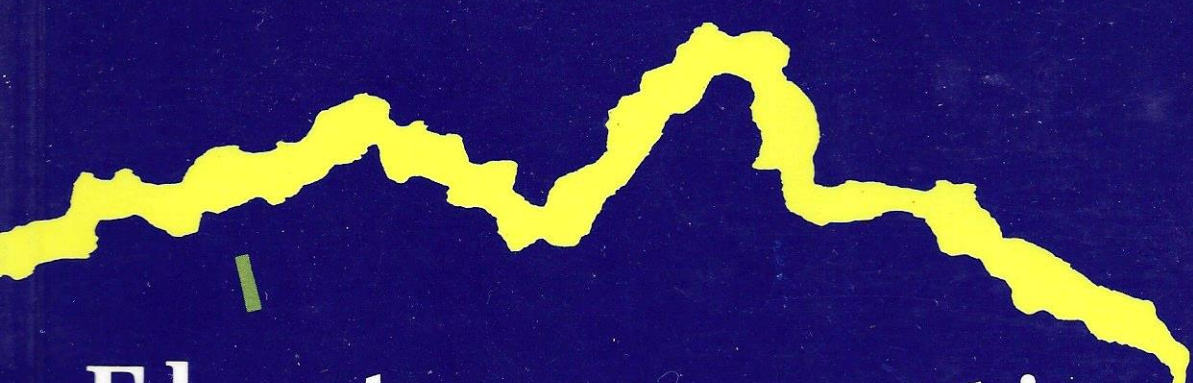
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Electromagnetism

Units 10–13

Unit 10

Revision exercises

Unit 11

Alternating
currents

Unit 12

Maxwell's
equations and
electromagnetic
waves

Unit 13

Electromagnetic
waves 1:
Propagation
without
absorption

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$$\mathbf{e}_x \cdot \mathbf{e}_x = \mathbf{e}_y \cdot \mathbf{e}_y = \mathbf{e}_z \cdot \mathbf{e}_z = 1 \quad \mathbf{e}_x \cdot \mathbf{e}_y = \mathbf{e}_y \cdot \mathbf{e}_z = \mathbf{e}_z \cdot \mathbf{e}_x = 0$$

$$\mathbf{e}_x \times \mathbf{e}_y = \mathbf{e}_z \quad \mathbf{e}_y \times \mathbf{e}_z = \mathbf{e}_x \quad \mathbf{e}_z \times \mathbf{e}_x = \mathbf{e}_y$$

Products of vectors in cartesian coordinates

For vector $\mathbf{a} = a_x \mathbf{e}_x + a_y \mathbf{e}_y + a_z \mathbf{e}_z$ and vector $\mathbf{b} = b_x \mathbf{e}_x + b_y \mathbf{e}_y + b_z \mathbf{e}_z$,

$$\mathbf{a} \cdot \mathbf{b} = a_x b_x + a_y b_y + a_z b_z \quad \mathbf{a} \times \mathbf{b} = \begin{vmatrix} \mathbf{e}_x & \mathbf{e}_y & \mathbf{e}_z \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

Gradient of scalar field ψ

$$\text{grad } \psi = \nabla \psi = \frac{\partial \psi}{\partial x} \mathbf{e}_x + \frac{\partial \psi}{\partial y} \mathbf{e}_y + \frac{\partial \psi}{\partial z} \mathbf{e}_z$$

Divergence and curl of vector field $\mathbf{A}$

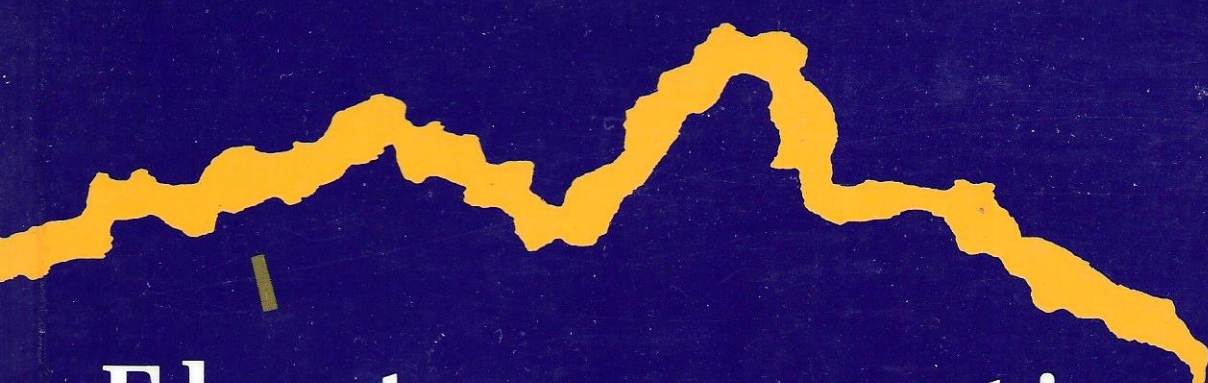
$$\text{div } \mathbf{A} = \nabla \cdot \mathbf{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} \quad \text{curl } \mathbf{A} = \nabla \times \mathbf{A} = \begin{vmatrix} \mathbf{e}_x & \mathbf{e}_y & \mathbf{e}_z \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ A_x & A_y & A_z \end{vmatrix}$$

Conversion between spherical polar and cartesian coordinates

$$x = r \sin \theta \cos \phi \quad y = r \sin \theta \sin \phi \quad z = r \cos \theta$$

SMT356 Units

- | | |
|---|--|
| 1 Mathematical preliminaries | 9 Electromagnetic induction and magnetic energy |
| 2 Electrostatics 1:
Fields and forces | 10 Revision exercises |
| 3 Electrostatics 2:
Potential and potential energy | 11 Alternating currents |
| 4 Dielectrics | 12 Maxwell's equations and electromagnetic waves |
| 5 Electrostatic field calculations | 13 Electromagnetic waves 1:
Propagation without absorption |
| 6 Magnetic fields and forces | 14 Electromagnetic waves 2:
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| 8 Magnetic materials | 16 Generation of electromagnetic waves |



Electromagnetism

Units 14–16

Unit 14

Electromagnetic
waves 2:
Absorption in
media; reflection
at surfaces

Unit 15

Waveguides and
resonant cavities

Unit 16

Generation of
electromagnetic
waves

Fundamental physical constants

Symbol	Quantity	Value
c	speed of light in vacuum	$2.998 \times 10^8 \text{ m s}^{-1}$
μ_0	permeability of free space	$4\pi \times 10^{-7} \text{ H m}^{-1}$ (or kg m C^{-2})
ϵ_0	permittivity of free space	$8.854 \times 10^{-12} \text{ F m}^{-1}$ (or $\text{C}^2 \text{ N}^{-1} \text{ m}^{-2}$)
$1/4\pi\epsilon_0$	(factor for Coulomb's law)	$8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
e	charge on proton	$1.602 \times 10^{-19} \text{ C}$
m_e	electron mass	$9.110 \times 10^{-31} \text{ kg}$
m_p	proton mass	$1.673 \times 10^{-27} \text{ kg}$
h	Planck's constant	$6.626 \times 10^{-34} \text{ J s}$
N_A	Avogadro's number	$6.022 \times 10^{23} \text{ mol}^{-1}$

Useful conversion factors

1 ångström (Å)	10^{-10} m	1 horsepower (hp)	745.7 W
1 mile	1.61 km	1 electronvolt (eV)	$1.602 \times 10^{-19} \text{ J}$
1 litre (l)	10^{-3} m^3	1 kilowatt hour (kW h)	$3.600 \times 10^6 \text{ J}$
1 gauss (G)	10^{-4} T	1 degree ($^\circ$)	$(\pi/180) \text{ rad}$

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SMT359 Book1
Science: Level 3



The Open University

Electromagnetism

An introduction to Maxwell's equations



Book 1: An introduction to Maxwell's equations

Book 2: Electromagnetic fields

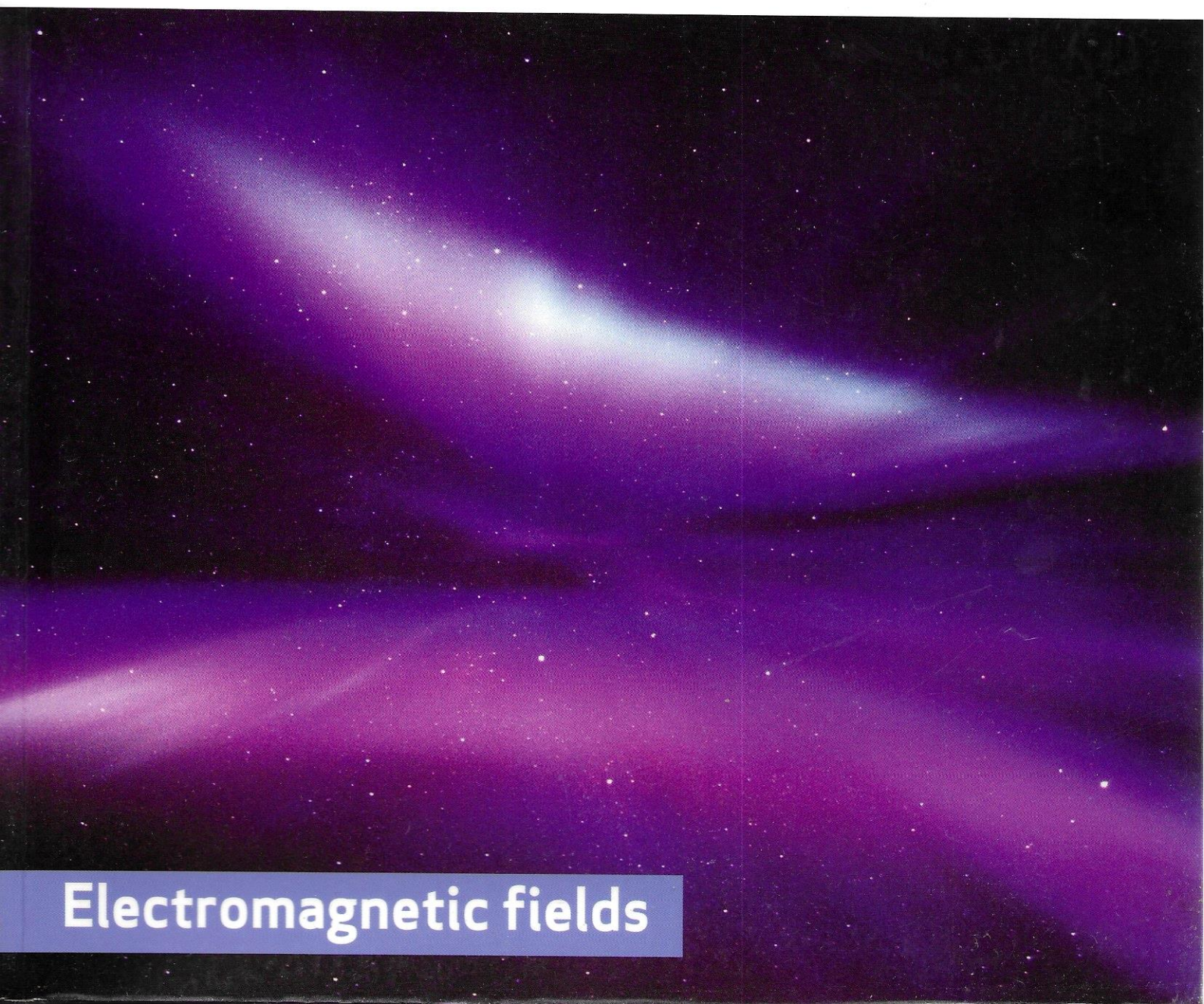
Book 3: Electromagnetic waves

SMT359 Book2
Science: Level 3



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Electromagnetism



Electromagnetic fields



Book 1: An introduction to Maxwell's equations

Book 2: Electromagnetic fields

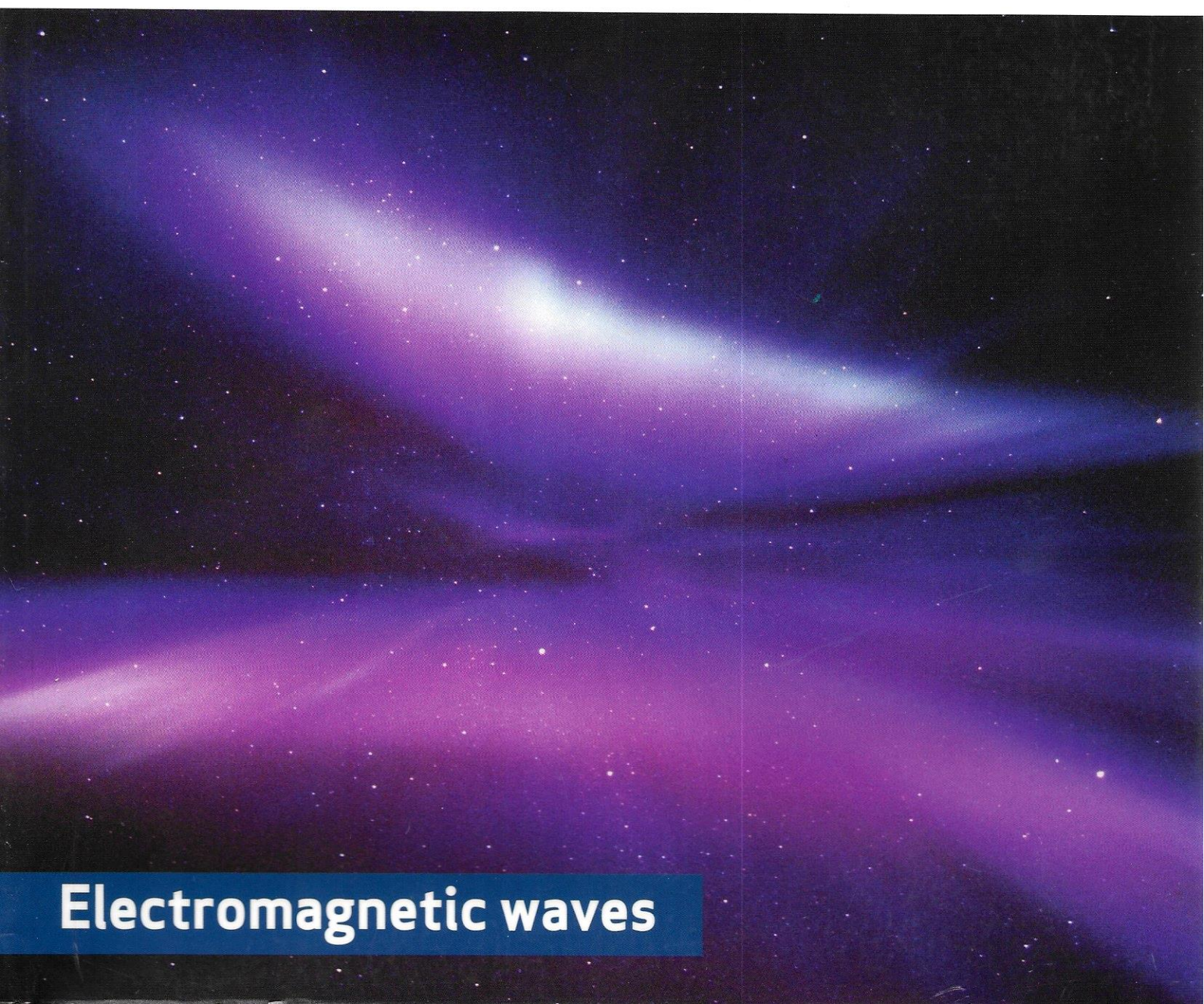
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Electromagnetism



Electromagnetic waves



Book 1: An introduction to Maxwell's equations

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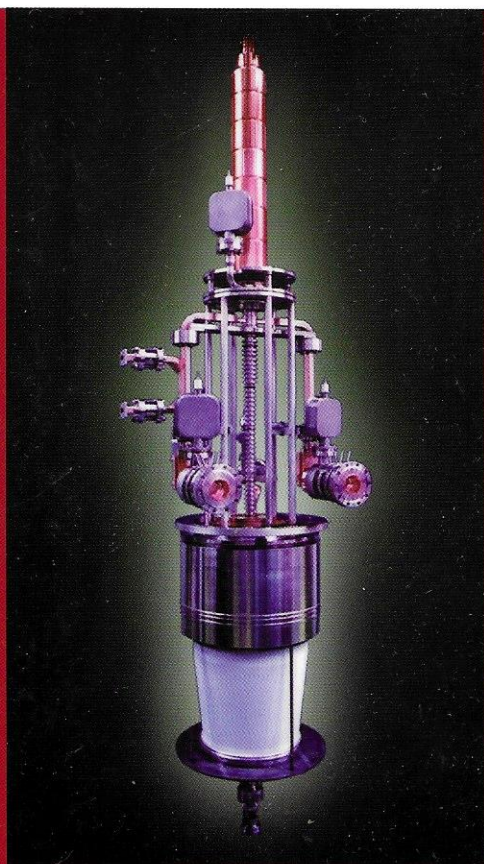
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Electromagnetism: experiments, applications and simulations



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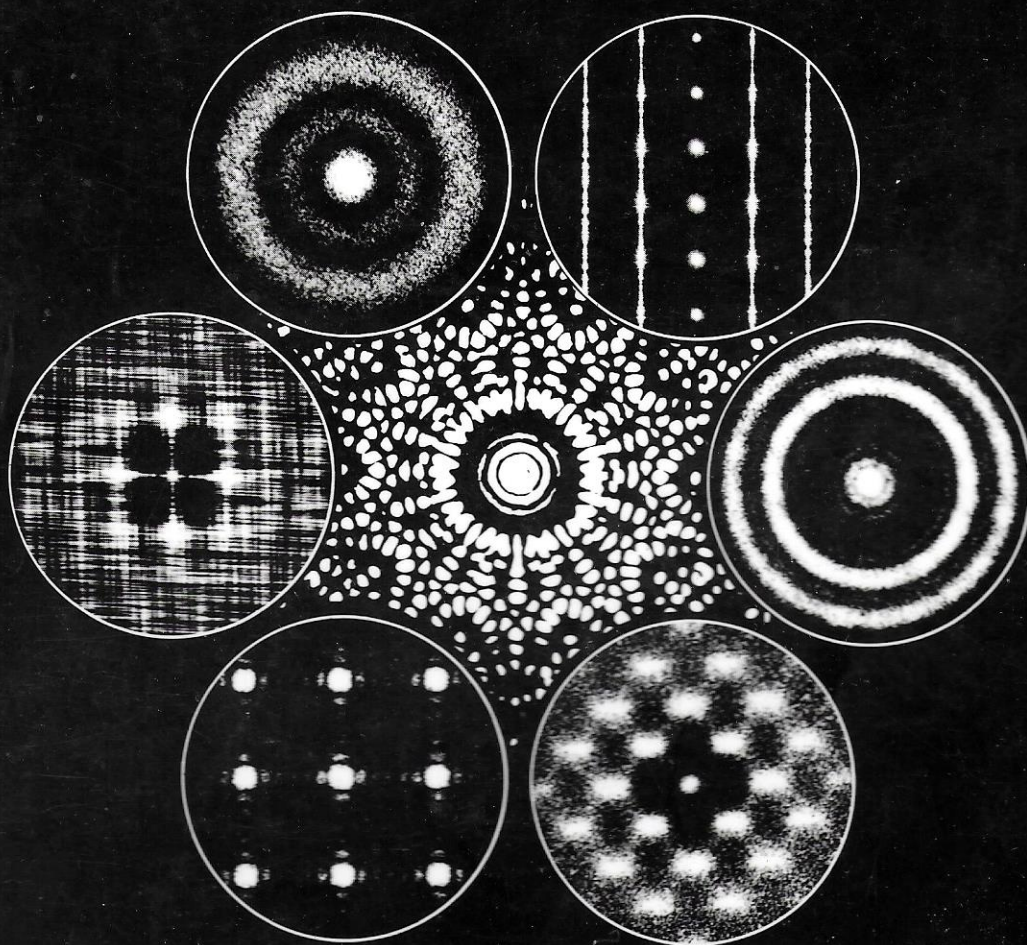
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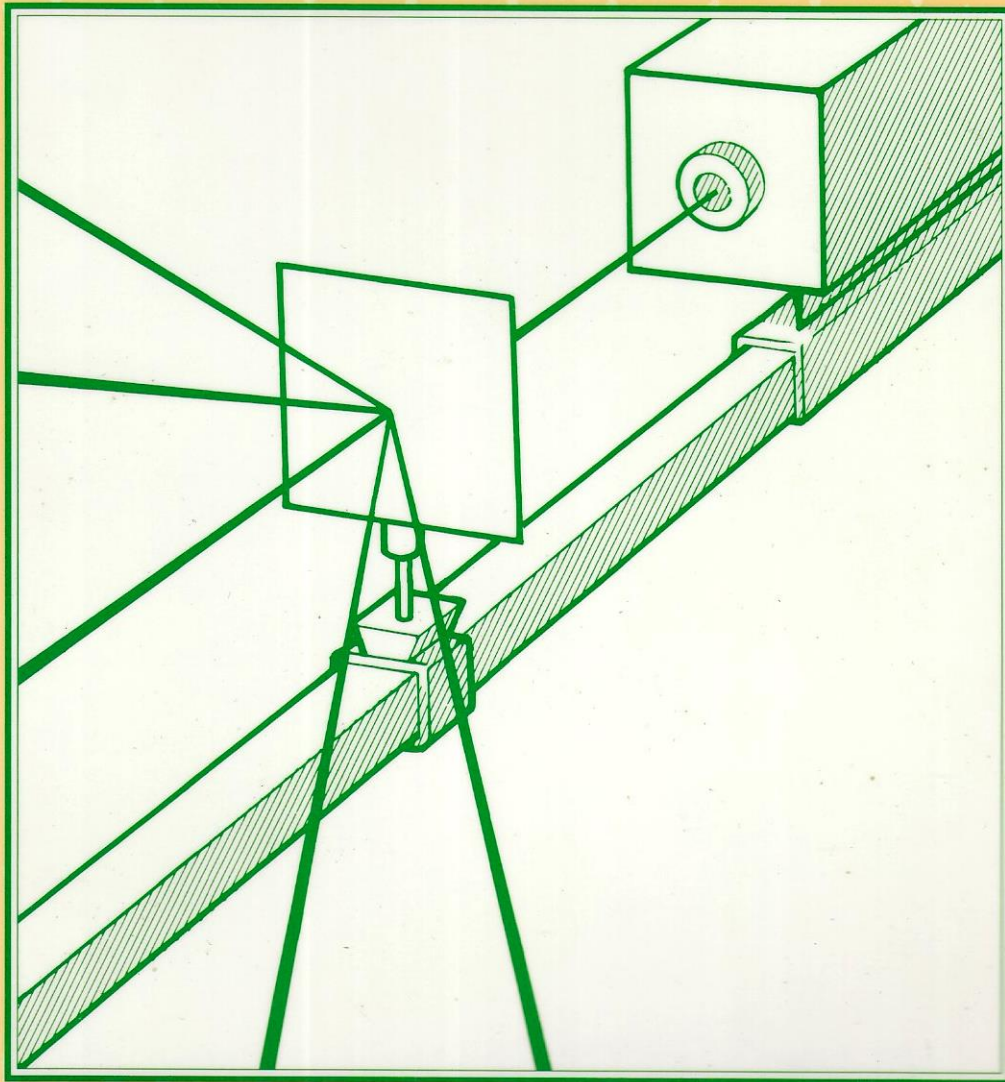
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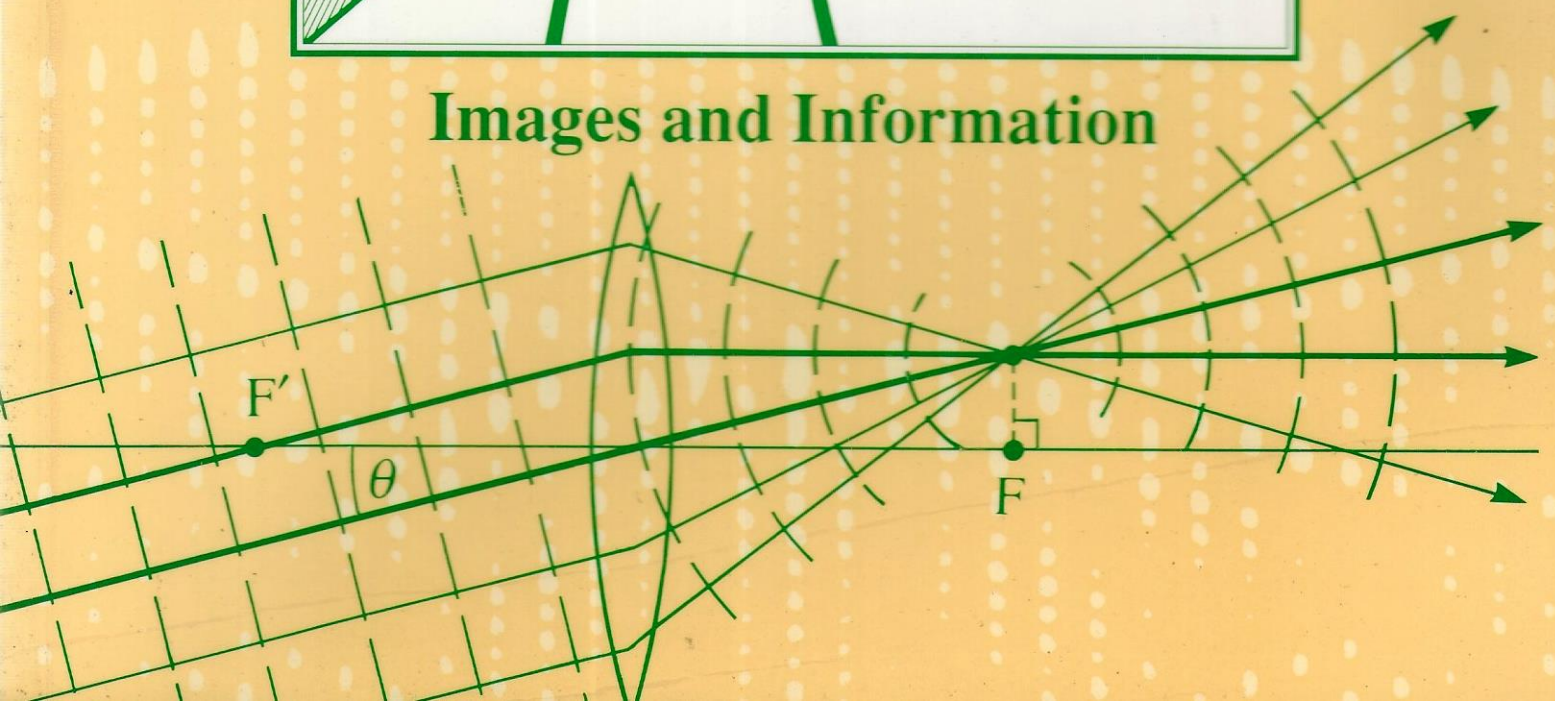


Units 1 & 2

An Introduction to Imaging



Images and Information



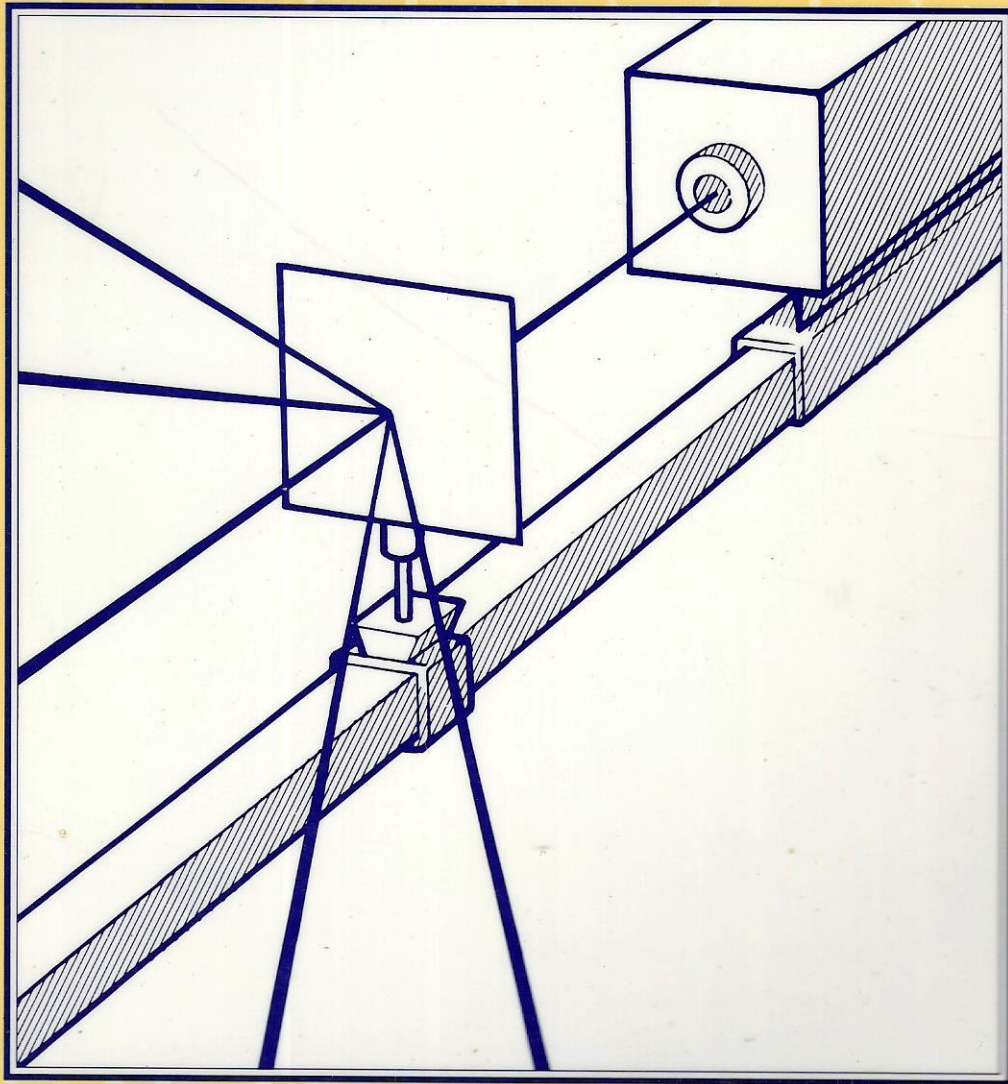


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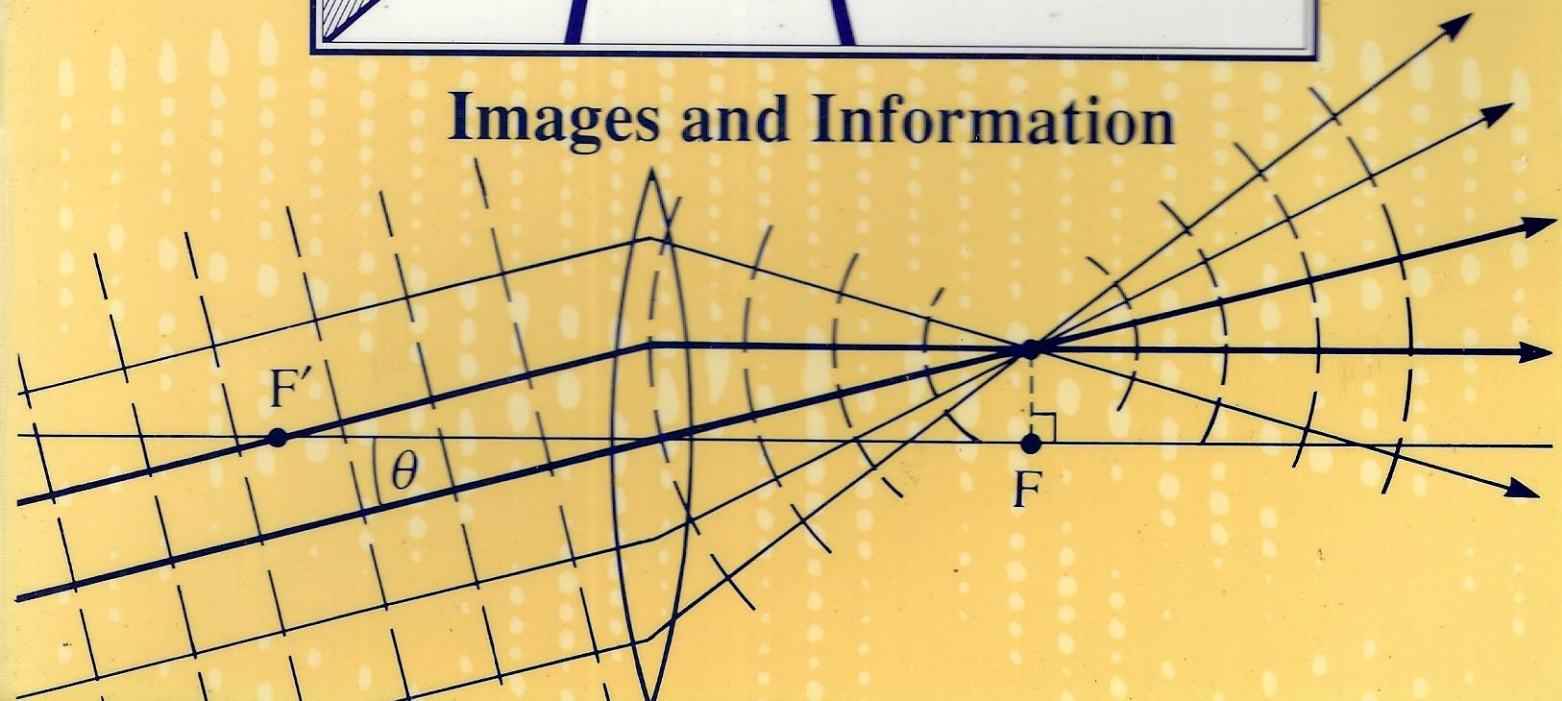


Unit 5

Coherent and Incoherent Illumination



Images and Information





Unit 6 Producing an Image: Lenses

Units 7 and 8 Improving the Image: Spatial Filtering





Units 9 and 10 The Recording and Reproduction of Visual Information (An Introduction to Holography)



IMAGES
INFORMATION



Case Studies:

Unit 11 The Crab Nebula

Unit 12 The Mariner 9 TV Experiment



IMAGES
INFORMATION



Case Studies:

Unit 13 Imaging Dislocations with
an Electron Microscope

Unit 14 Albert Crewe's Atom



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Case Studies:

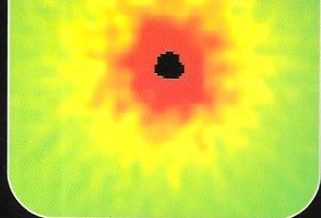
Unit 15 Ultrasonic Imaging of
the Human Foetus

Unit 16 The EMI-scanner



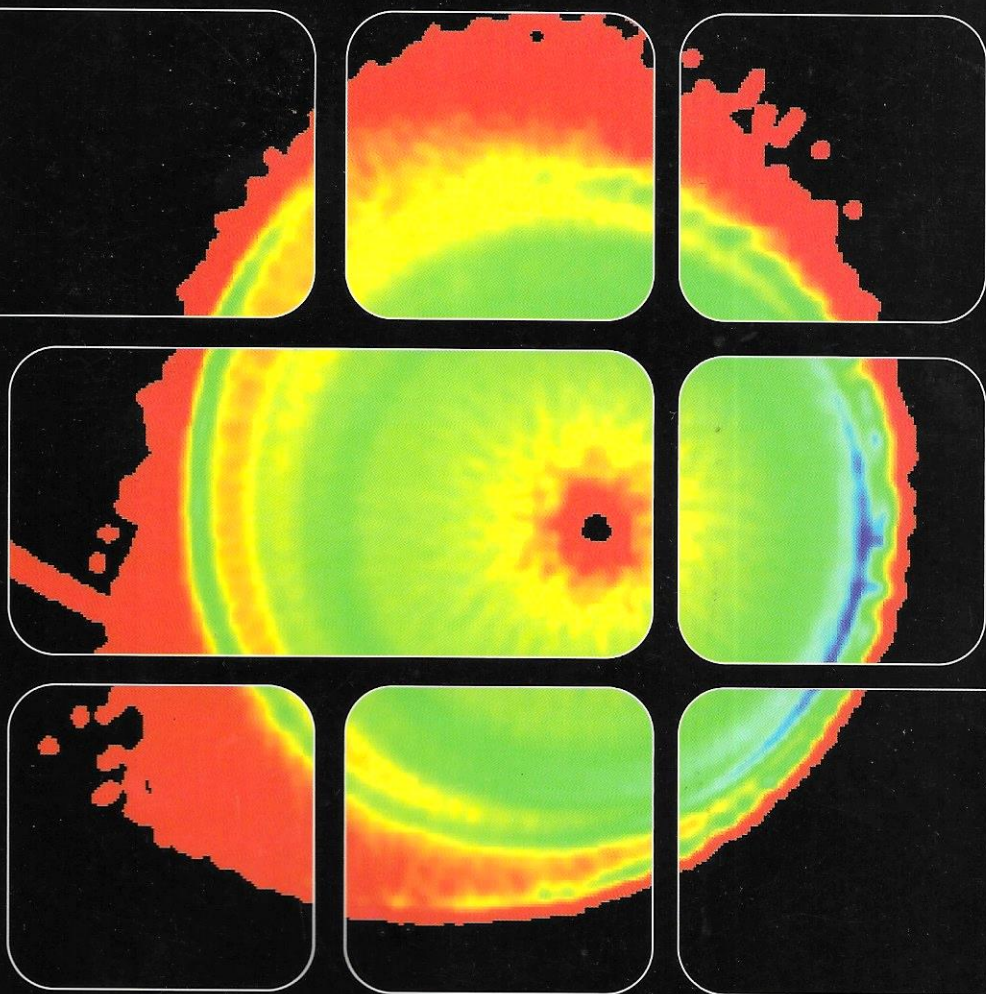
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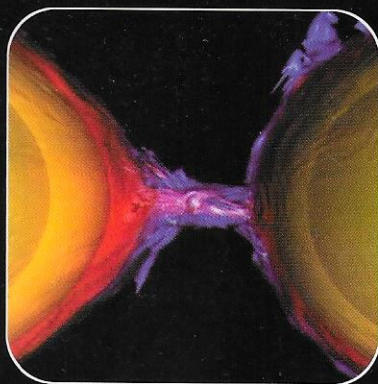


Accretion Power in Astrophysics

Juhan Frank, Andrew King and Derek Raine



CAMBRIDGE



Accretion Power in Astrophysics

examines accretion as a source of energy in both binary star systems containing compact objects, and active galactic nuclei. Assuming a basic knowledge of physics, the authors describe the physical processes at work in accretion discs and other

accretion flows. The first three chapters explain why accretion is a source of energy, and then present the gas dynamics and plasma concepts necessary for astrophysical applications. The next three chapters then develop accretion in stellar systems, including accretion onto compact objects. Further chapters give extensive treatment of accretion in active galactic nuclei, and describe thick accretion discs. A new chapter discusses recently discovered accretion flow solutions.

The third edition is greatly expanded and thoroughly updated. New material includes a detailed treatment of disc instabilities, irradiated discs, disc warping, and general accretion flows. The treatment is suitable for advanced undergraduates, graduate students and researchers.

Front cover illustration: Simulation of the eccentric accretion disc in the SU UMa system OY Car in Superoutburst by Dr J. Murray, University of Leicester.

Back cover illustration: 3-D simulation of the mass transfer stream in a semi-detached binary by Patrick Motl, Louisiana State University.

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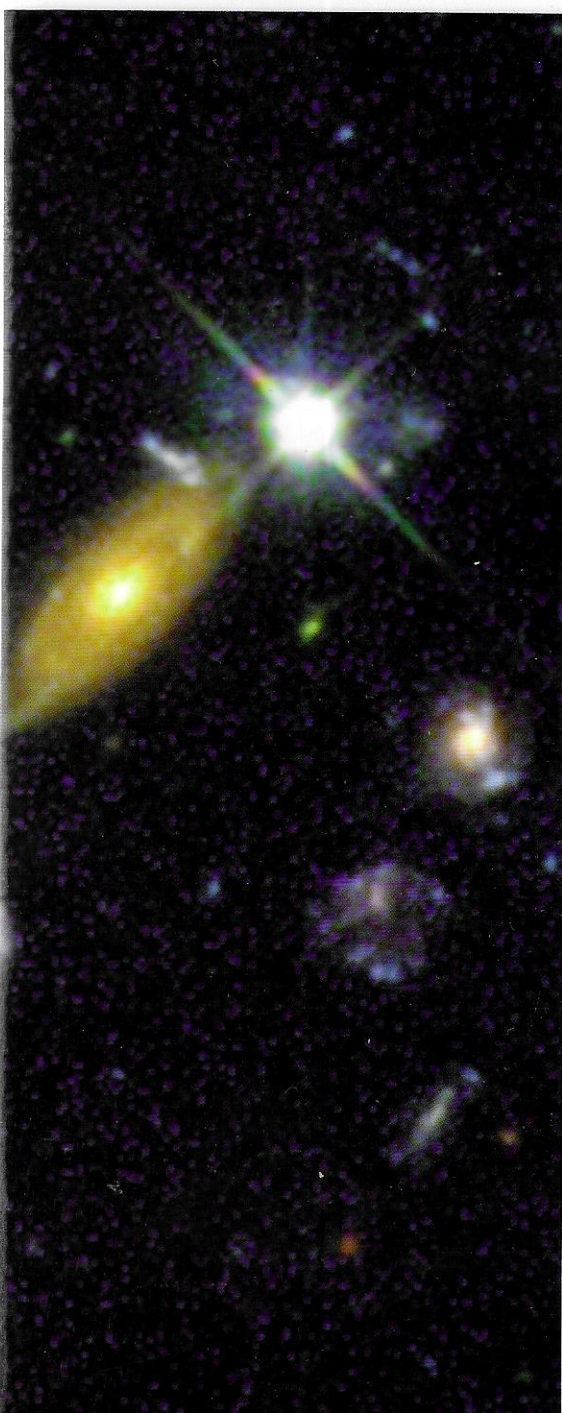
active**galactic***nuclei*

B R A D L E Y M P E T E R S O N



AN INTRODUCTION TO

activegalacticnuclei



How can we test if a supermassive black hole lies at the heart of every active galactic nucleus? What are LINERs, BL Lac objects, N galaxies, broad-line radio galaxies, and radio-quiet quasars and how do they compare? This timely textbook answers these questions in a clear, comprehensive, and self-contained introduction to active galactic nuclei – for advanced undergraduates and graduate students in astronomy and physics.

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Cover photograph: Part of the 'Hubble Deep Field', a ten-day exposure obtained with the Wide-Field Planetary Camera-2 on the Hubble Space Telescope in December, 1995.

This represents a 'true color' map in which the colors are exaggerated: blue objects, such as star-forming regions, appear very blue, and red objects, such as old stellar systems, are very red.

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